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JOINT COMMITTEE ON ATOMIC ENERGY

SUMMARY-ANALYSIS OF HEARINGS MAY 27–29, AND JUNE 3–7, 1957

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

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SUMMARY-ANALYSIS OF HEARINGS HELD MAY 27–29 AND JUNE 3–7, 1957, ON THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

Introduction

During late May and early June the Joint Committee on Atomic Energy held 8 days of public hearings on the nature of radioactive fallout and its effects on man. It was the intent of these hearings to emphasize the scientific subject matter related to the fallout problem, and to leave broader policy issues to subsequent consideration. The hearings, including material introduced for the record and a comprehensive bibliography, will probably be the most extensive library of information on fallout yet to appear in one document.[1]

The hearings covered in detail the whole cycle of fallout from its inception in the detonation of nuclear weapons, through its scattering about in the atmosphere and descent to earth, and finally its uptake by and effect on human beings, animals, and vegetation. Testimony covered a breadth of scientific knowledge from physics to pathology, and from geology to genetics, as it relates to fallout. Some 50 experts from the major scientific areas involved were invited to present testimony before the committee and submit statements for the record. All sessions were open to the public.

The hearings accomplished several things. One thing was clarification of many important scientific points. Another was putting into better perspective much of the available scientific data on fallout. Most helpful, in this respect, were experimental round-table discussions among some of the expert witnesses. The discussions helped to point up the areas of agreement and to outline more clearly the areas of continuing disagreement.

The hearings served to bring out distinctions that must be made between fact and value judgment, and served to emphasize how difficult it is to give precise scientific definition to such words as "clean," "safe," and "hazardous," so that these words acquire exact meanings.

The scope of the subject matter covered in the hearings is so broad and often so technical and detailed that a comprehensive analysis and evaluation is likely to involve a broad segment of the scientific and lay community in this country, and others, for many months to come. The purpose of this summary analysis is more immediate: To put down in simple terms a statement of what the hearings were about and what the main issues were. It is to be recognized that

[1] The oral testimony will constitute a major portion of the printed hearings which will also include statements inserted for the record. Selected reprints of previously published technical reports and scientific journal papers are also included. The extensive bibliography, prepared by Mrs. Ruth A. Little, Legislative Reference Service, Library of Congress, is an important part of the record of the hearings.

preparing even a summary necessarily implies making value judgments as to what is to be summarized. The summary does not cover all of the wealth of information available in the print of the hearings.

The proper discussion of fallout, its nature, its effects, and its policy implications requires an understanding of certain facts and concepts that are not ordinarily before the layman's eyes in easily understandable terms. The fallout hearings were aimed at bringing out these ideas and facts so as to promote a better understanding by the Congress and the public of this complex question. Much of the information contained in the print of the hearings is technical. One of the purposes of this summary analysis is to simplify and clarify this information.

The Joint Committee on Atomic Energy went to great lengths, first, to insure that all of the major areas of background subject matter in the sciences would be covered and, second, that important points of difference on what the facts are, or what they mean, would be covered so as to bring out clearly what differences exist.

On May 22, 1957, a statement of the scope and approach of the forthcoming fallout hearings, and an outline of the subject matter were made available to all prospective witnesses and to the public. This material included specific questions to guide witnesses as to points the committee felt should be covered or emphasized to assure a full and balanced presentation. Witnesses were picked out primarily from the point of view of their scientific competence and familiarity with particular aspects of the fallout problem. Obviously, not all scientists in the country meeting that criterion could come before the committee to testify. The committee tried to pick out a representative sample and to achieve a balanced presentation reflecting varied points of view.

The committee intended that the basic responsibility for adequate coverage and presentation of the subject matter would fall on the expert witnesses themselves. One of the most satisfying aspects of the hearings to the Congress and to the country should be the unstinting efforts of the expert witnesses to see that the subject matter was fully covered and made understandable.

Before coming to his own conclusions concerning fallout effects, a person should understand the basic scientific facts now available. Information in the field of fallout effects, as for many other scientific fields of inquiry, is far from complete. However, these hearings should provide enough information to help a person to begin to understand the problems and issues involved, to see what the present scope of information is, and to see the areas yet to be explored.

SUMMARY OF KEY POINTS

Some general observations may be made on the results of the hearings:

1. *Origin of fallout.*—It was pointed out that all nuclear explosions can be expected to produce some radioactive materials. However, certain kinds of explosions produce very much less radioactivity than others. Although there is no such thing as an absolutely "clean" weapon (that is, there is no such thing as a nuclear weapon detonation completely free of accompanying radioactivity), the amount of the

radioactivity produced can be substantially altered in relation to the size of the explosion.

2. *Distribution of fallout.*—There was substantial, but far from complete, agreement on what happens to radioactive debris produced in man's environment, how much is there now, how and where it is distributed, and how much is in man himself. There was considerable evidence presented to indicate that in no part of the atmosphere is fallout uniformly distributed and that, therefore, the effects of fallout on the world's population could not necessarily be expected to be uniform.

3. *Biological effects of radiation.*—There was general agreement that any amount of radiation, no matter how small the dose, increases the rate of genetic mutation (change) in a population. There was, on the other hand, a difference of opinion as to whether a very small dose of radiation would produce, similarly, an increased incidence of such somatic (nongenetic) conditions as leukemia or bone cancer, or a decrease in life expectancy, in a population.

4. *Tolerance limits.*—There was general agreement that there is a limit to the amount of radioactivity and, hence, to the amount of fission products that man can tolerate in his environment. The extent to which existing and future generations will be affected by manmade radiation was shown to be intimately tied to certain decisions, moral as well as scientific, that must be made as to how much radiation can be tolerated by the peoples of the world.

5. *Effects of past tests.*—It was clearly shown that man's exposure to fallout radiation including strontium 90 is and will be in general small, *for the testing already done*, compared with his exposure to other, "normal background" sources of radiation (a fraction of 1 to 10 percent), and even compared with variations in "normal background" sources. But it was not agreed on how this information should be interpreted.

6. *Effects of future tests.*—There were differences of opinion on how to forecast the consequences of further testing. The differences hardest to reconcile appear to be those concerning the biological effects of radiation. Pending a resolution of differences, it would appear from the information presented that the consequences of further testing over the next several generations at the level of testing of the past 5 years [2] could constitute a hazard to the world's population. It is very difficult, if not impossible, to forecast with any real precision the number of people that would be affected.

7. *Effects of nuclear war.*—The catastrophic nature of the radiation effects from a multiweapon (atomic and hydrogen bombs) attack on the United States were clearly portrayed. This, of course, could be applied to any nation.

These points will be discussed in more detail.

MAJOR UNRESOLVED QUESTIONS

A number of unresolved questions emerged from the hearings. Among the chief of these are—

1. How "clean" can nuclear weapons actually be made? The solution to this question lies in the future of weapons development.

[2] It has been estimated that about 50 megatons equivalent yield of fission products have been put into the atmosphere so far by all countries.

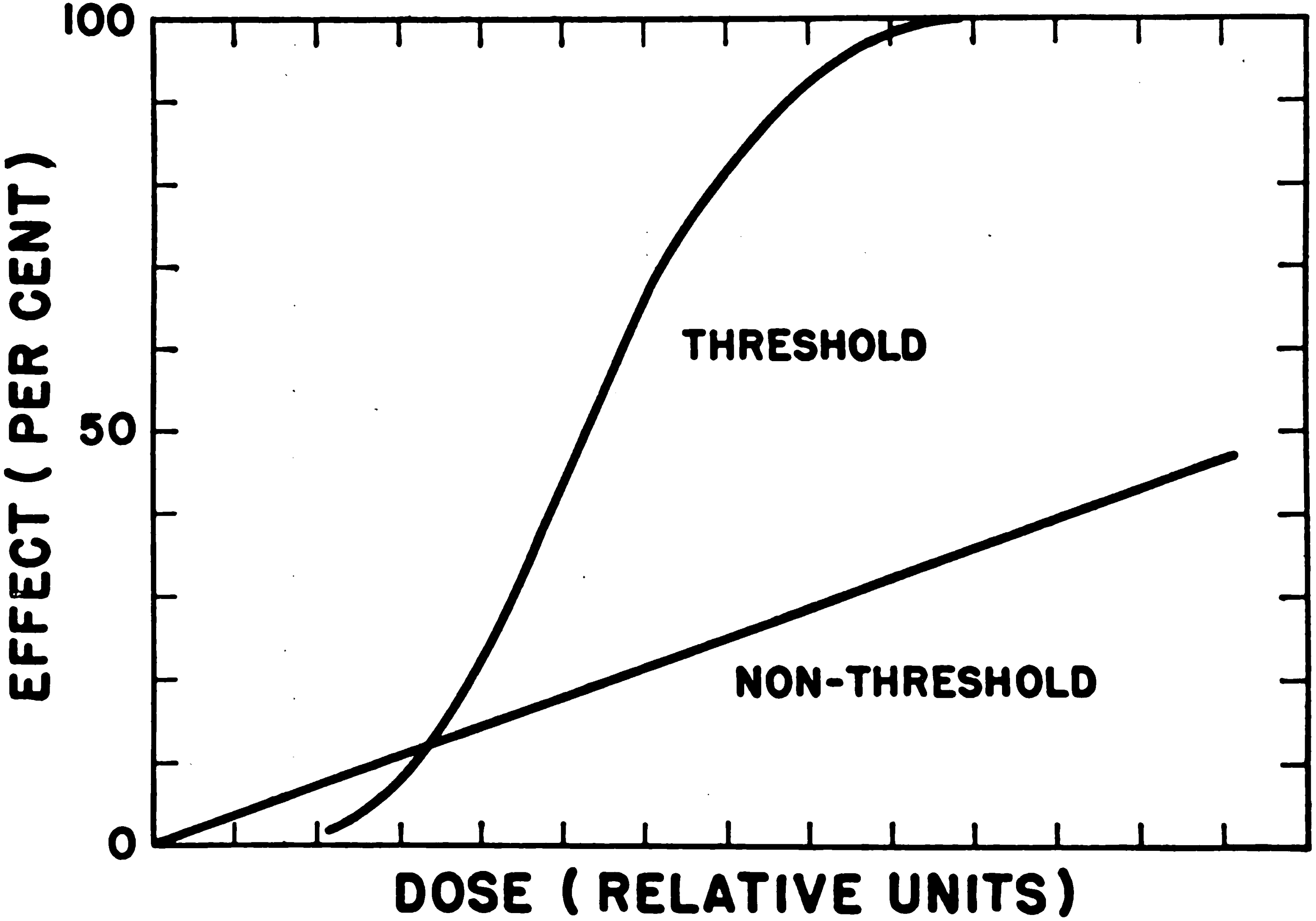

FIGURE 3.—A pictorial representation of the difference between a threshold and a nonthreshold situation. Dose increases to the right. Note that the non-threshold line is a straight line; it needn't be. (See p. 15.) [Figure reprinted from testimony of Drs. Langham and Anderson, Los Alamos Scientific Laboratory.]

THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

MAY 27, 28, 29, AND JUNE 3, 1957

PART 1

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Mr. RAMEY. As well as from food and milk, and so on?

Colonel HARTGERING. We feel that our data shows this without question, sir.

Mr. RAMEY. Is the amount they pick up significant in relation to these other amounts?

Colonel HARTGERING. This is a very difficult question to answer because it depends on the location of the individual. For an individual who is working for the Department of Defense or the Atomic Energy Commission at the test site, the amount that he picks up during the test period is significant. For the individual several thousand miles away this is just a part of it, and maybe it is a small fraction of the total that he will pick up over the next period of time. In our opinion the peaks particularly are due to the inhalation and do not reflect transmission through the food cycle. No doubt the food cycle is important and also contributes to man's radioactivity at late times.

Mr. RAMEY. Doctor, are the methods that you have used such that they are readily adaptable to monitoring strontium in bone?

Colonel HARTGERING. The methods we used are the same as Dr. Kulp uses in measuring the amounts in bone. We start out with several gallons of liquid urine and reduce it to a small volume and do essentially the same chemical separation and measuring procedures that he uses.

Senator ANDERSON. Thank you very much. This has been a very interesting discussion. I certainly commend you on the work that is being done in the field. It is very encouraging.

Now we come back to where we should have started this afternoon had we been able to stay on schedule: Dr. Langham and Dr. Anderson of Los Alamos Scientific Laboratory.

STATEMENT OF DR. WRIGHT LANGHAM,[1] ACCOMPANIED BY DR. E. C. ANDERSON,[2] LOS ALAMOS SCIENTIFIC LABORATORY

(A comprehensive report by Dr. Langham and Dr. Anderson on the hazards of strontium 90 appears on p. 1348.)

Dr. LANGHAM. The remarks that I plan to make, I would like to limit to a consideration of the long-term fallout problem in preference to getting involved in the discussion of what might be the result of

[1] Received a bachelor of science degree in science from the Oklahoma A. and M. College at Goodwell, Okla., in 1934, and a master's degree from the Oklahoma A. and M. College at Stillwater, Okla., in 1935. From 1935–37 he held a position of research chemist with the Agricultural Experimental Station at the Oklahoma A. and M. College at Goodwell. From 1937–38 he did graduate work at Iowa State College, Ames, Iowa, working in the field of organic chemistry. From 1939–41 he returned to the Agricultural Experimental Station at Goodwell, Okla., as acting experiment station director. In 1941 he entered the University of Colorado, from which he was awarded a doctor of philosophy degree in biochemistry with a minor in biology in 1943. In the same year he joined the staff of the Manhattan district's metallurgical laboratory at the University of Chicago, where he worked on the chemistry of plutonium. In 1944 he was transferred to the Los Alamos Scientific Laboratory, Los Alamos, N. Mex., to study the toxocology of plutonium and to develop methods of diagnosing exposure of personnel to this material. In 1946 he became the group leader of the biological and medical research group of the laboratory. Since then he has investigated a number of major problems concerning the biological and medical aspects of atomic energy development. These include rates of retention and excretion of internally deposited radioactive isotopes, toxicology, and physiology of tritium in man, relative biological effects of ionizing radiations of different types and energies, including bomb gamma rays and neutrons, incapacitating effects of massive doses of radiation, hazards from accidental noncritical detonation of atomic weapons, and the biological and medical implications of worldwide radioactive fallout. He is at present group leader of the biomedical research group and assistant division leader (for research) of the Los Alamos Scientific Laboratory's Health Division, and is an associate professor of biochemistry with the University of California at Los Angeles. He is a member of the following committees and organizations: Subcommittee on Internal Tolerances of the International

shorter-term fallout in the event we are actually involved in a nuclear war.

If we look over the fission products and the radioactive debris that results from weapons detonations, we find we can immediately eliminate the majority of the fission products as a long-term hazard on the basis of their physical half-life, their biological half-life, or the degree to which they enter into the ecological cycle.

Further inspection of these results indicate that there are really only three which might be of serious consideration. One is plutonium 239. It has not been mentioned in this meeting perhaps, but every time a bomb has been exploded it has probably made about as much plutonium as was burned up in the detonation. Therefore in these atomic clouds we do have plutonium.

We have only two other isotopes of appreciably long half-life which have a possibility of being hazardous. Those are strontium 90 and cesium 137. Let us dispose of the plutonium problem first.

Plutonium is a manmade element, at least in any great abundance. It is not taken up by plants and the discrimination factor is going from soils to plants for plutonium is a matter of 10,000. Plutonium is extremely poorly absorbed from the gut. The discrimination in this case is another factor of ten to the fifth or a hundred thousand.

Then we can immediately say that the concentration of plutonium in the bones of the individuals will be only of the order of one-one hundred millionth of what it is in the soil.

Knowing the amounts of plutonium that are made in these detonations, it is immediately possible to eliminate plutonium for any further consideration in the long-term fallout problem.

Let us now come to cesium 137. When a bomb is detonated the fission products form at various stages after the detonation. Cesium 137 and strontium 90 are formed with a halftime of about 3 minutes, which means they are formed late in the history of the fireball. Consequently, they are not trapped as much as are other isotopes in the heavy debris which falls out locally.

Since they are formed at approximately the same times in the history of the fireball, cesium and strontium tend to go together. So where we find one, we will find the other; in approximately the ratio they occur in the fission mixture, which is almost 1 to 1.

Then every time we have a millicurie per square mile of strontium 90, we will have a millicurie per square mile of cesium 137 deposited.

In order to evaluate the cesium 137 hazard, let us refer to natural potassium. The body contains approximately 150 grams of potassium. This is vital to life. Potassium, however, is radioactive, having in it

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Footnote continued from preceding page.

Commission for Radiological Protection; Subcommittee on Internal Radiation Tolerances of the National Committee for Radiation Protection; Subcommittee on Incineration of Radioactive Wastes of the National Commission for Radiation Protection; Subcommittee (Chairman) on the Relative Biological Effects of Ionizing Radiation of the National Commission for Radiation Protection; Subcommittee on Toxicity of Internal Emitters of the National Academy of Sciences and National Research Council; the American Association for the Advancement of Science; Radiation Research Society; Health Physics Society; Sigma Xi Honorary Scientific Research Society. (Submitted by witness.)

[2] Date and place of birth: August 23, 1920, Rock Island, Ill. Education: Bachelor of arts, Augustana College and Theological Seminary, 1942; doctor of philosophy (chemistry), Chicago, 1949. Work history: Assistant analyst, chemistry metallurgical laboratory, Chicago, 1942–44; Los Alamos Scientific Laboratory, 1944–46; Member: Staff biophysics, 49—; Rask-Orsted fellow, Copenhagen, 1951–52; Chemical Society, natural radiocarbon liquid scintillation counter; low-level radio activity measurements; neutrino detection; nuclear radiation dosimetry. (Submitted by Atomic Energy Commission.)

the isotope potassium 40. The number of gamma disintegrations occurring from potassium in the human body is approximately 450 per second.

In other words, from the natural potassium in our bodies, we are absorbing 450 gamma disintegrations per second. The number of beta disintegrations are approximately 9 times higher.

So therefore, we are getting somewhere around 9 times 450, which is about 4,000 beta disintegrations per second from potassium.

All of this is equivalent to approximately a tenth of a microcurie of activity. The amount of activity, taking into consideration the absorption factors in tissue, will result in our receiving a radiation dose of approximately 20 milliroentgens per year. This constitutes approximately 20 percent of our natural background of 100 milliroentgens per year.

When we measure, using the human counter at Los Alamos and the crystal counter at the Argonne Laboratory, the cesium to potassium ratio in people, we find that this ratio is approximately 0.05, meaning, then, that the amount of radiation that we receive from the cesium in the bodies of people as a result of weapons testing so far, is about one-twentieth of what we receive from the natural potassium background level.

The present concentration, then, of cesium 137 in people is contributing approximately 1 milliroentgen per year. It is of interest, of course, to everyone to consider what about the genetic dose. Since it is pretty well established that we have had to and will continue to live with background, the question then becomes one of whether cesium 137 concentrates in the gonads imposing on the population a genetic dose out of proportion to the 1 milliroentgen per year delivered to the total body?

Analysis of the gonads of animals injected with cesium 137 show there is no concentration above normal in these organs. The principal site of concentration of cesium 137 is the same as that of potassium—the muscle. So we might expect muscular people to have a little more cesium than do fat people. We might expect men to have more than women and variation in cesium 137 over the country is but not more than a factor approximately 2 or 3 at most. The dose that we receive to our gonads as a result of cesium 137 fallout is, therefore, approximately equal to the dose that we receive to the rest of the body. We can say with confidence that cesium 137 is increasing our gonad dose by 1 milliroentgen per year, which is again approximately only 1 percent of the radiation dose our gonads receive from natural background.

This, then, definitely says that it is hard to imagine cesium 137 being either a genetic threat or a somatic threat, unless we can say that continued weapons testing or fallout from the stratosphere is going to increase this level by manyfold. Cesium 137 when it falls upon the soil becomes tightly bound and associated with the soil colloids and cannot be leached off very readily and consequently is not taken up by plants except perhaps to the extent of 1 percent. So at most the concentration in the plants we eat will be only about 1 percent of the concentration in the soil.

Another question, then, might be, is it possible that this material, as is the case with strontium 90, concentrates in the bone or in some

tissue from which it has a very slow biological turnover time. Using human subjects we have measured the turnover time of cesium 137. There measurements show that it concentrates in the muscle and the muscle constitutes a major portion of the body mass. Therefore, it is not concentrating a great amount of radiation in a small volume of tissue.

When we measure the cesium 137 turnover time in people, we find that half of it is disappearing every 110 to every 140 days. Then there is no long-term highly concentrating mechanism in the body. We can assume that if weapons tests continued at the present rate, the cesium 137 level in people, which is in reality a measure of the amount of cesium that is falling out in any given period of time and not the total integrated amount of cesium, will remain essentially constant with a constant weapons test rate.

If we accelerate the test rate, we will increase the level of cesium 137 in people by a proportionate amount to the amount of fission that is involved in the weapons tests.

Remember, we are not talking about megatons of explosive yield in this problem. We are talking about the megaton equivalents of fission products put into the biosphere. We can explode bombs with a greater thermonuclear component (and no greater fission component), thereby increasing greatly the yield of weapons fired, and not increase greatly the amount of fission products added to the biosphere. It is my understanding that Dr. Neuman's number of 2.2 megatons per year is referring to fission yield injected into the biosphere, and not yield of total explosive force fired.

Mr. Ramey. When you say "we," you mean the United States. That would not necessarily mean some other country that was just learning how to make bombs?

Dr. Langham. Anybody who is firing atomic weapons is being referred to, or should be, in terms of the amount of fission products that he puts into the biosphere, not the total yield of his weapon.

Mr. Ramey. I understand that. I meant in relation to getting more explosive yield with less fission through some mechanism.

Dr. Langham. Getting more explosive yield through less fission is in all probability what any country will be doing.

Senator Anderson. We did not do it the first year we started our work. Did we not wait a few years and gradually develop into this and therefore do you not think other countries not as advanced may do the same thing we did?

Dr. Langham. We have a pretty good idea that the British and Russians are already doing the same as we did. In other words, the thermonuclear yield or the thermonuclear weapons tested both by the Russians and British are an attempt to get more yield which involves less fission.

Senator Anderson. I think we would all agree to that. It is a fusion type to a great degree.

Dr. Langham. It doesn't matter whose weapon it is. The thing that is of critical importance is not the total yield of the weapon from the point of view of the problem we are discussing, but how much fission they had to employ in order to get that yield.

Senator Anderson. You did not think Dr. Neuman did not understand that, did you?

Dr. LANGHAM. I do not know whether he did or not. He said megatons of bombs.

Senator ANDERSON. No; he did not. You were not following him very closely. He had exactly the same definition you used.

Dr. LANGHAM. That is fine. What I want to say is that this does not mean—and I want to be sure that the audience understands—that 2.2 megaton yield is the limit to the amount of testing that we can do. It is 2.2 megatons of fission yield injected into the biosphere.

Senator ANDERSON. I though Dr. Neuman made it clear, and I am glad you did also.

Dr. LANGHAM. Then I am sorry. This, then, will bring us to the point where I think we can say that the cesium 137 problem is certainly and will remain secondary to the strontium 90 problem. This makes, of course, the strontium 90 problem considerably more interesting and focusses attention in the cesium 137 work on using cesium 137 to study the mechanisms whereby radioactive fission products are distributed in the biosphere. It is for that reason that studies in this direction certainly should continue. It is very possible that cesium 137, or what we learn by cesium 137 until it hits the ground and begins to enter the ecological cycle, can tell us a great deal of what happens to strontium 90 before it hits the ground.

Cesium 137 is much easier to measure than strontium 90. So we may be able to collect considerably more data on strontium 90 by inference to cesium 137 work.

We have just received a phone call from Dr. Rose in Chicago who asked us to read something into the statement that he entered into the record with regard to the cesium 137 problem. Dr. Marinelli and Dr. Rose have just measured the cesium 137 content in a number of people from South America. Their result indicates that the average found in those people was about 14 micromicrocuries of cesium per gram of potassium, and that compares to the measured value in the United States of 34; 14 versus 34. This signifies, then, that if strontium and cesium do indeed go together, then there is a factor of 2 difference between the fallout in South America and the fallout in the United States. This would indicate again what you have heard voiced many times today, that despite the fact that one might think of great variations over the face of the earth, these variations do seem to be confined to factors of 2 and 3. This is a very important point.

As far as I am concerned, this is what we have to say with regard to the cesium 137 problem. I would like to mention the strontium problem insofar as we see it and perhaps add a little more to what has already been said, with regard to equilibrium levels, and its relation to the present test rate.

First I would like to put down the numbers that have been quoted variously, and some of them here today, for the estimated strontium 90 level in the bones of people at the point of maximum fallout which will be in about 1970 or 1975, and really show you how these values agree.

Dr. Libby in his recent speech has estimated that the level would be from 1.7 to 2.5 micromicrocuries of strontium 90 per gram of calcium at equilibrium, assuming no more weapons tests. This estimate was made on the basis of ecological data, assuming a discrimination factor

of from about 20 to about 30, somewhat in disagreement with the discrimination factor you have heard expressed by Dr. Neuman.

Senator ANDERSON. May I ask, is that a comparable figure to the figure of 8 which he was using?

Dr. LANGHAM. That is right.

Senator ANDERSON. 20 to 34?

Dr. LANGHAM. 20 to 30.

Dr. Kulp in his recent article—and I am talking now about the United States of America and the upper northern section, the section that is supposed to have the most fallout—made an estimate of approximately 2 $\mu\mu c$ per gram of calcium, again based on ecological considerations.

We have made estimates at Los Alamos on the basis of ecological factors also. The average equilibrium level for the United States we come out with as 3.1. We have taken Dr. Kulp's bone data and made a correction that we think is justified. I have not discussed it with him. On that basis we come out with 3.2 for the equilibrium level for the upper United States.

Dr. Eisenbud in his consideration this morning, talking about New York, estimated an equilibrium level of 4.1. We have also derived a value from milk data by merely taking not the average for New York but the average for Chicago, New York, and other milksheds, and we obtain a value of 3.5.

I think it is amazing that we do get agreements this close together when these are derived by different means. The thing perhaps we should be considering is the average for the population belt of the world, because the major portion of the fallout is occurring in that area which has the major number of inhabitants. If we do this, we can estimate for the area between 10° N. and 60° N. latitude, approximately 2.5 micromicrocuries of strontium 90 per gram of bone calcium. These are average values for the area.

Senator ANDERSON. Are all these figures based on no more testing?

Dr. LANGHAM. These are all based on no more testing; yes.

Senator ANDERSON. I don't understand why you start on that assumption.

Dr. LANGHAM. You must start on that assumption and it is the first step in going on to trying to estimate what will happen later. This is the reason.

We can make estimates for the entire world and obtain an average of the world population. Dr. Kulp has made such an estimate. For the entire world he has estimated a value of about 1.3. We have estimated this value by two different methods—by considering ecological factors and by using Dr. Kulp's bone data—and when we do, we come out with a value of 1.7, again amazingly good agreement.

Senator ANDERSON. Doctor, does that not also point up how accurate your observation was a minute ago? You were talking about cesium and the study that had been made in Latin America and you said Latin America it was half of what it was in North America. You said this is also very similar to the strontium figure and the strontium figure would show that, because you have a figure of 2.5 here and something like 1.3 there which is certainly comparable to the figures you had a moment ago.

Dr. LANGHAM. Thank you. I didn't notice that myself.

Senator ANDERSON. Is it accidental or does it seem to work out that way?

Dr. LANGHAM. I think as our data get better and better we are going to find these things beginning to pull together. I can remember when the arguments here were that this may be as high as 50. Now we have it narrowed down so that the disagreement is at most a factor of 2. Remember, I am talking about averages over a specific area, and there is a certain finite probability that any person or that a person or a few persons in any proscribed area will run as much as 2 to 3 times these values and I am now talking about the very factor that Dr. Neuman was introducing, his V–1 factor that he put into his equation.

On this basis, then, we can do a little more with the data as far as what does it mean with regard to present and future tests.

Let me now talk in terms of the population average of 2.5. I am talking now about the area of 10 north to 60 north latitude. Present levels are only about one four-hundredth of the workers permissible value if we want to assume that the maximum permissible level that we will permit the population in this area to reach on an average is 1,000 micromicrocuries per gram of calcium, the occupational tolerance—remember, Dr. Kulp did this some time ago and got criticized for it because it is as inferred that he was recommending we let the population do this, he was not so inferring but was merely trying to tie the values to something that we have accepted and we have accepted that the maximum permissible level for the working or occupied population shall be 1,000 micromicrocuries per gram of calcium. It is pretty well established insofar as the national and international conferences on radiation protection are concerned, that if we are including a large segment of population of nonworking people, then we should lower this by a factor of 10, which puts it to 100 micromicrocuries per gram.

Dr. Neuman has preferred to use 50 here, because of the statement that was made in the National Research Council and National Academy of Science report, in which it was merely said it may be advisable in the case of children to lower this even further.

We can now set up a simple proportionality between strontium 90 equilibrium megatons of fission to date as Dr. Kulp did, in which he took Dr. Libby's data on stratospheric storage and fallout, and he said the present situation we face must be the result of the injection of approximately 50 megatons of fission yield into the biosphere.

If this be true we set up a simple proportionality and say that 2.5 is to 50 megatons as x is to 1,000 or 100 micromicrocuries per gram of calcium, and we can calculate the number of megatons of fission weapons we would have to fire all at one time (and let them fall out at one time) in order to bring the average of the population belt up to these various levels.

When one does this, he comes out with 20,000 megatons of fission products injected into the biosphere would bring the population to an average level of 1,000 micromicrocuries per gram of bone calcium.

Two thousand megatons exploded all at once (and letting it fall out all at once) would bring the average up to 100 micrimicrocuries per gram of calcium.

Now we get into the areas of uncertainty. The things that are most important, far more important than factors of 2 difference in distribution or factors of 2 difference in the equilibrium level in people. For example, we have right here a disagreement of a factor of 10 depending on whether we use the occupational or nonoccupational permissible level. If we want to use Dr. Neuman's level of 50, we have then a disagreement of a factor of 20.

Then our major source of disagreement is on what do we dare let the level in the population reach on the average. Let us do something more with this. Let us say that a factor of 3 is enough to cover the difference in distribution and the discrimination factor. Then we would say we would want to divide this number by 3 (20,000) which would give us roughly 7,000, and in this case (2,000) would give us roughly 700, which would say we could explode 700 megatons before we would take a chance of bringing many people up to the nonoccupational exposure.

Let us assume that the tail on the stable strontium distribution curve that Dr. Kulp has presented, in which he said that it was skewed distribution. Let us take the attitude of the ultraconservative and say because this tail exists and we do not have a normal distribution we had better apply a factor of greater than 3. Some people have done this. They have said the bone data themselves, show a spread of a factor of 10. Let us introduce a factor of 10. That would mean we would have to divide the 7,000 by 10, which would give us 700, and if we divide the 700 by 10 we are now down to 70 megatons. In other words, there is on this basis at the present time a factor of about 200 to 300 disagreement between the ultraconservative and the person who dares be somewhat radical. Where does this variation lie?

A factor of 10 lies in this point where some person might say it does not hurt to let people reach 1,000 micromicrocuries, another says 100 and another says even lower.

There is another factor of 10 in what we assume for the spread in non-homogenity of distribution of this material in people and soil.

Then if we multiply 10 by 10 we have a factor of 100. So 100 out of our 200 or 300 disagreement comes in 2 points, which points out immediately, the important things for us to do.

Senator ANDERSON. Doctor, would you excuse me just a second. I do not follow you for a second there. When you have 25 over 3 you come out with 7,000. When you have 25 over 10, why don't you come out with 2,000?

Dr. LANGHAM. You are right. That is what I should come out with, 2,000 and 200. In other words, 2,000 and 200 instead of 700 and 70.

I think my statement was that the most important things for us to do is to work on what really should be the average maximum permissible level that we dare allow a large segment of the population to reach.

The second thing that we should do is continue the type of work that Dr. Kulp is doing, and others, and study by all means the distribution of strontium 90 in soils, the distribution of strontium 90 in bones, and anything which will give us a cue as to the nonuniformity aspect of the problem.

Do we divide by 10; do we divide by 3; or don't we divide at all?

The Atomic Energy Commission's research program, that of the

Division of Biology and Medicine, is pointed in this direction. What does this mean in terms of future tests?

This, as I said, was a consideration based on no more weapons testing and then firing a number of megatons and making the assumption that they all came down at once and they were all injected into the biosphere at once.

If we continue to test weapons at the present rate, and this is something that I know has worried Senator Anderson a great deal, we cannot establish yet what the increasing rate of weapons testing is. In Castle—and I do not mean weapons testing, I meant to say the rate of injection of fission products into the biosphere. It does not correlate necessarily with megatons of weapons exploded.

In Castle we exploded a lot. In Redwing we exploded quite a number of megatons of yield but less fission products were injected.

So it is hard to say that we do have any kind of an increasing rate in weapons testing which will allow us to say what we will go to if we continue to accelerate at our present rate. But we can say this: If our present situation is the result of 50 megatons injected into the biosphere and this has occurred over 5 years, then we are roughly contributing on an average about 10 megatons per year to the biosphere. If we continue at this rate, there are two numbers that one can use. Only two estimates have been made, one from the British and one by Dr. Libby.

Dr. Libby has stated that if we continue at our present rate, we will reach equilibrium at about 8 times the level that we would be at if we stopped immediately.

For the population belt we said it was 2.5 micromicrocuries per gram of calcium. If we take 8 times that, that gives us roughly 20 micromicrocuries per gram of calcium will be the average level in the people in the population belt if Dr. Libby's factor of 8 is right and if we continue to test by injecting 10 megatons per year into the biosphere.

This is not in disagreement with somebody who said 24 this morning.

Mr. Ramey. That was Dr. Kulp.

Dr. Langham. If you want to consider the United States, the United States is somewhat higher. In other words, here we would have certainly as much as 3. So 3 times 8 equals 24 which was the figure Dr. Kulp quoted for the United States.

There is one other figure. Let us enlarge this still further. If this is the average and we say we can let a factor of 3 take care of nonhomogenities, then there may be a few people who will be 3 times the average in the United States, or 72 micromicrocuries, which is getting up close to the recommended maximum level of 100.

If we want to be even more conservative and introduce a factor of 10, then we must multiply 24 by 10 which gives us 240 which is a factor of 2 above what has been specified as the maximum permissible level.

Again we must emphasize the necessity of our settling this idea of what is the area of uncertainty. This can only be done by statistical treatment of large numbers of samples.

The British come up with a somewhat more conservative number. On the basis of their soil and air and water measurements, they have said that if the present rate of testing continues, Britain will have 200 millicuries of strontium 90 per kilometer squared, which is roughly

500 millicuries per square mile, which is 900 micromicrocuries per gram of calcium in the soil. If we assume a discrimination factor of 10 which I like better than Dr. Neuman's factor of 8—but I think you will agree the difference is not great—then this would mean according to the British figures the average in the population of Britain would reach 90 micromicrocuries per gram of calcium indefinitely or in about 100 years of testing which is almost our maximum level of 100.

Now if we multiply that by 3 in order to allow for nonhomogenity of distribution, we have a segment of population that could conceivably go as high as 270. Then immediately we get to the most critical point, and that is: What does this mean in terms of risk to the population of the United States and to the population of the world? This is a subject about which I feel very keenly, but I know that the committee has lined up the finest experts in the country on this subject, so I think probably this is a good place for me to stop unless you want to drag it out of me by questions.

Senator ANDERSON. No; I only want to know if I understand this at the end. Is that comparable to the 100 safe figure that was being used?

Dr. LANGHAM. We have 2 bases. We have Dr. Libby's factor of 8, which gives us a level of about 24 micromicrocuries at equilibrium if we continue testing. That is on the average. So we can multiply it by 3, assuming that there is a factor of 3 spread. That would give us 72. This would then mean that there was a finite probability that a few people might go this high when the average is 24. Our maximum permissible level for larger areas of population is 100 micromicrocuries. So we can see if we continue testing weapons at our present rate, or rather injecting fission products into the biosphere at the present rate, then we would level off at about one-fourth of the maximum permissible level on the average.

There is a possibility that some people would be almost there.

If we take the British values based on soil deposition in Britain and use their factor—instead of saying 8, they really say we will reach equilibrium between 12 and 14 times, and there is a disagreement between the British and Dr. Libby—then what corresponds to the 24 in the United States goes up to 90 in Britain. What corresponds to the 72 in the United States goes up to 270 in Britain.

Senator ANDERSON. Is that 270 to be compared with the 100 which is the safe level?

Dr. LANGHAM. Yes. This is to say that the average on the basis of the value of 90 would be below the safe level if you want to call 100 safe.

Senator ANDERSON. But those people who are above the average would be right at the level.

Dr. LANGHAM. And these people with 270 would be a factor of almost 2 above this level.

Representative HOLIFIELD. Almost 3.

Dr. LANGHAM. Yes.

Senator ANDERSON. How many years would it take to achieve that?

Dr. LANGHAM. According to the British it would be reached in 100 years and according to Dr. Libby in about 50. Which of these levels you may select depends entirely on the crucial biological point, which is, is it leukemic and bone sarcoma response to radiation dose linear with dose, or is it a threshold? If it is a threshold, we have to

look at this (100 micromicrocuries) as the maximum permissible level. If it is a nonthreshold response we may look at this as an average level and try to decide what the risk is averaged over the entire population or averaged over any segment of the population.

What a nonthreshold response essentially says is that for every increment increase in dose there is an equal increment increase in effect and theoretically there is no maximum permissible level. There is an extremely small probability that any amount of radiation, the amount we wear on our wristwatches or the amount that we get from our natural potassium is going to harm somebody.

So the whole point of which of these numbers we can accept will depend upon our making a value judgment how much is atomic energy worth in cases of leukemia and bone cancer on a probability basis, averaged over the entire population or a certain segment thereof.

Senator ANDERSON. Thank you very much. I can say from personal acquaintance I know how long and hard you have worked in this field and I am very grateful to you for your testimony.

The next witness is Dr. Anderson.

Dr. ANDERSON. Mr. Chairman, I have nothing to add to the formal statement Dr. Langham made. I was in attendance only to answer questions.

Senator ANDERSON. Before we proceed with a discussion period with our several witnesses, there are several things that I would like to insert in the record at this point. First a statement by Wright H. Langham and Ernest C. Anderson. Next an article from Science Magazine, by Ernest C. Anderson, Robert L. Schuch, William R. Fisher, and Wright Langham, and finally a statement by L. D. Marinelli and J. E. Rose of the Argonne National Laboratory.

(The material referred to follows:)

SR-90 AND CS-137 IN RELATION TO THE PROBLEM OF WORLDWIDE RADIOACTIVE FALLOUT

By Wright H. Langham and Ernest C. Anderson, Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex.

Although a number of isotopes are present in the fission mixture, the fallout of Sr-90 from weapons testing programs is the principal concern. Sr-90 is the most important isotope because of its similarity to calcium, long physical and biological half-time and high relative fission yield. These factors lead to high incorporation in the biosphere and a long residence time in bone. General contamination will result in the bones eventually reaching an equilibrium state with the Sr-90 in the biosphere.

Accepting Libby's postulation of three types of fallout (local, tropospheric, and stratospheric), levels as of the fall of 1956 were about 25 mc./mi.^{2} for the upper midwestern and northeastern sections of the United States, 16 mc./mi.^{2} for the section between 50° N. and 10° S. latitude, and about 4 mc./mi.^{2} for the rest of the world. These general values are variable, depending upon local rainfall and other meteorological patterns.

The observed levels of Sr-90 in bones of various ages are in good agreement with those calculated on the basis of a simple model of skeletal growth, remodeling and exchange. Using the data of Kulp for adults and children normalized to this model, an average equilibrium value of 3 μc. Sr-90/g. Ca is calculated for about 1975. Estimation of the equilibrium value from ecological discrimination factors suggests approximately the same average level. The normal spread of values for stable strontium and Sr-90 in human bones and for Cs-137 in people suggests that there is a very low probability that many people will show levels more than three times the average. On the basis of an equilibrium concentration of 3 μc. Sr-90/g. Ca resulting from detonations to date, about 18,000 megatons of fission could be injected at once into the biosphere before the average value would equal the maximum permissible level of 1,000 μc./g. Ca (the MPL for

industrial workers), and 1,800 megatons could be injected before reaching an average of 100 $\mu c./g.$ Ca (the MPL for large areas of the population).

The above approach to the problem suggests (assuming no more weapons tests) that the average equilibrium level from weapons already tested may be about 3 percent of the MPL for the general population with a spread of from 1 to 9 percent. In terms of lifetime bone dose, these values are from 1/400 to 1/2,800 of the minimum dose from Ra 226, which has produced nonpathological bone changes. The biological significance of present and future predicted levels and whether average values may be applied to the general population depends on whether such chronic responses as bone sarcoma, leukemia, etc., to Sr-90 deposition are threshold or nonthreshold phenomena.

Estimates as to the number of megatons of fission that may be injected into the biosphere before Sr-90 becomes a serious health hazard to the general population vary by a factor of about 200. It is this variation in opinion that is responsible for much of the public confusion. Two factors that contribute a major portion of this wide uncertainty are:

1. The heterogeneity as to distribution of Sr-90 uptake in the skeleton as a function of diet and geographic location; and
2. Lack of information as to actual leukemogenic and tumorogenic response of man as a function of radiation dose.

Increased research effort to narrow the uncertainties in these two factors would seem to be desirable.

Measurements of present levels of Cs-137 in people indicate that it is of little significance in the potential hazard of radioactive fallout from weapons testing programs. Because of the chemical similarity of cesium and potassium, it is convenient to report cesium levels as Cs/K ratios. Potassium is an essential body constitutent and is itself naturally radioactive. The normal body potassium contribute 20 mr/year of the total natural yearly radiation dose of 100 mr. The present average Cs-137/K-40 total disintegration ratio is about 0.05. Taking into consideration their respective energies, the radiation dose from present levels of Cs-137 is only one-twentieth of that from natural K-40, or about 1 mr/year. This is about 1 percent of the average total natural radiation dose. The amount of Cs-137 now present in the population of the United States averages 0.006 $\mu c.$, which is less than one-thousandth of the value given in the Recommendations of the International Commission for Radiological Protection as the maximum permissible level for the general population.

The short biological half-time of Cs-137 and its unavailability from soils will ensure that the levels in people will not continue to rise in the manner of Sr-90. The cesium levels will follow the rate of fallout and not integrated total accumulation.

Since Cs-137 does not show unusual concentration in the gonads, present levels in people will contribute only about 1 mr./year, or about 1 percent of the natural background level, to the genetic radiation dose.

The study of the distribution of Cs-137 should be continued to furnish information on fallout phenomena and to provide a measure of the rate of fallout and the amount of stratospheric storage, since this information might make considerable contribution to the solution of the Sr-90 problem.

[Reprinted from Science magazine, June 28, 1957]

RADIOACTIVITY OF PEOPLE AND FOODS

Ernest C. Anderson, Robert L. Schuch, William R. Fisher, Wright Langham[1]

The problems of widespread, low-level radioactive contamination from nuclear weapons testing have been increasingly before the public during the past year. The principal concern is the fallout and entry into the biosphere of strontium 90. There is general agreement that present levels of strontium 90 in foodstuffs and in the human body are far below the most conservative permissible amounts; however, the human burden of strontium 90 may be expected to rise as a result of deposition of stratospheric debris from weapons already (and subsequently to be) tested. Predictions based on conservative assumptions indicate that there remains a considerable margin of safety. If the rate

[1] Dr. Anderson, Mr. Schuch, and Dr. Langham are members of the biomedical research group at Los Alamos Scientific Laboratory, University of California, Los Alamos, N. Mex. Mr. Fisher, a former member of the group, is now at the University of Colorado School of Medicine, Denver.

of weapons testing continues to increase, however, this margin may eventually disappear.

Although the permissible levels contain inherent safety factors, it is essential that close attention be devoted to all aspects of the fallout problem during the next several years. Only in this way can advance notice of the possible approach to permissible levels be obtained and assurance given that they will not be exceeded inadvertently. Recent reports of the National Academy of Sciences-National Research Council Committee on the Biological Effects of Atomic Radiation (1) support the importance of systematic measurements of general levels of radioactivity in order that information on the rate of accumulation of extraneous radioactivities may be obtained while the latter are still below natural levels.

Large-scale production of nuclear power will create problems of a similar nature. A 100-megawatt (heat) reactor will, in one year of operation, produce the same quantity of long-lived fission products as the detonation of a 1-megaton fission bomb. The estimate of the United States nuclear power production rate by 1975 is 20,000 to 40,000 megawatts, and the United Kingdom expects to be producing 6,000 megawatts by 1965. Reactor-produced fission products constitute a much less immediate problem than those from a bomb test, since more control can be exercised over their immediate fate, but disposal of the fission products must eventually be made.

If disposal is to be simple enough to make nuclear power economically competitive, dispersal by natural means such as ocean burial or other means may have to be resorted to. This will increase the possibility that reactor-produced fission products may ultimately enter the food cycle and reach man. The basic problems of permissible body burdens and distribution mechanisms in the biosphere, therefore, are similar for bomb and reactor debris, and information gathered in the study of the former problems should prove valuable in the latter.

An extensive survey of strontium 90 levels (Project Sunshine) has been underway for several years, and the results have been reported by Libby (2–4) and by Kulp (5). Because strontium 90 and is daughter yttrium 90 emit only beta rays, analysis requires time-consuming and destructive chemical separations. Detailed studies of the temporal and spatial distribution of long-range fallout would be easier if they could be based on a gamma-emitting nuclide. The discovery of the presence of the fission product cesium 137 in human beings and in foodstuffs by Miller and Marinelli (6) provides a possibility of such an approach.

Similarity of the decay chains of the fission products of mass 90 and mass 137 indicates that distribution of cesium 137 and strontium 90 in bomb debris will be similar:

$$\text{Kr–90} \xrightarrow{\text{33 sec}} \text{Rb–90} \xrightarrow{\text{2.7 min}}$$
$$\text{Sr–90} \xrightarrow{\text{28 yr}} \text{Y–90} \xrightarrow{\text{64 hr}} \text{Zr–90 (stable)}$$
$$\text{I–137} \xrightarrow{\text{19 sec}} \text{Xe–137} \xrightarrow{\text{3.4 min}} \text{Cs–137} \xrightarrow{\text{27 yr}}$$
$$\text{Ba–137m} \xrightarrow{\text{2.6 min}} \text{Ba–137 (stable)}$$

Both nuclides have two gaseous or volatile predecessors with appreciable half-lives. Strontium 90 and cesium 137 are formed at relatively late times after bomb detonation and are not proportionally included in the larger and more refractory particles which fall out locally. Stratospheric storage and distant deposition will be high for both nuclides, and their ratio in distant fallout should be approximately that calculated from the known fission yields. Once strontium 90 enters the biosphere, its behavior becomes very complex. Its concentrations along the ecologic chain change slowly and reflect a summation of all past fallout. In addition, it enters plants both through the soil (in some relationship with available calcium) and by foliate absorption from direct fallout.

One very important and difficult problem is to determine the fraction of strontium 90 entering the ecologic chain by way of these routes. Cecium 137, however, is apparently poorly taken up from the soil by plants (7) and its biological half-times (8) are comparatively short (140 days in man (9) and 20 days in the cow (10)). These factors suggest that cesium in people and in milk and other foodstuffs may be a direct and relatively simple measure of fallout rate. One should be able, therefore, to make a direct determination of fallout rate as a

function of geographic location and time, as well as of changes in stratospheric storage following test operations, by measuring cesium 137 in biological materials. Cesium 137 measurements on soils might provide a more convenient method than strontium 90 measurements for estimating integrated fallout.

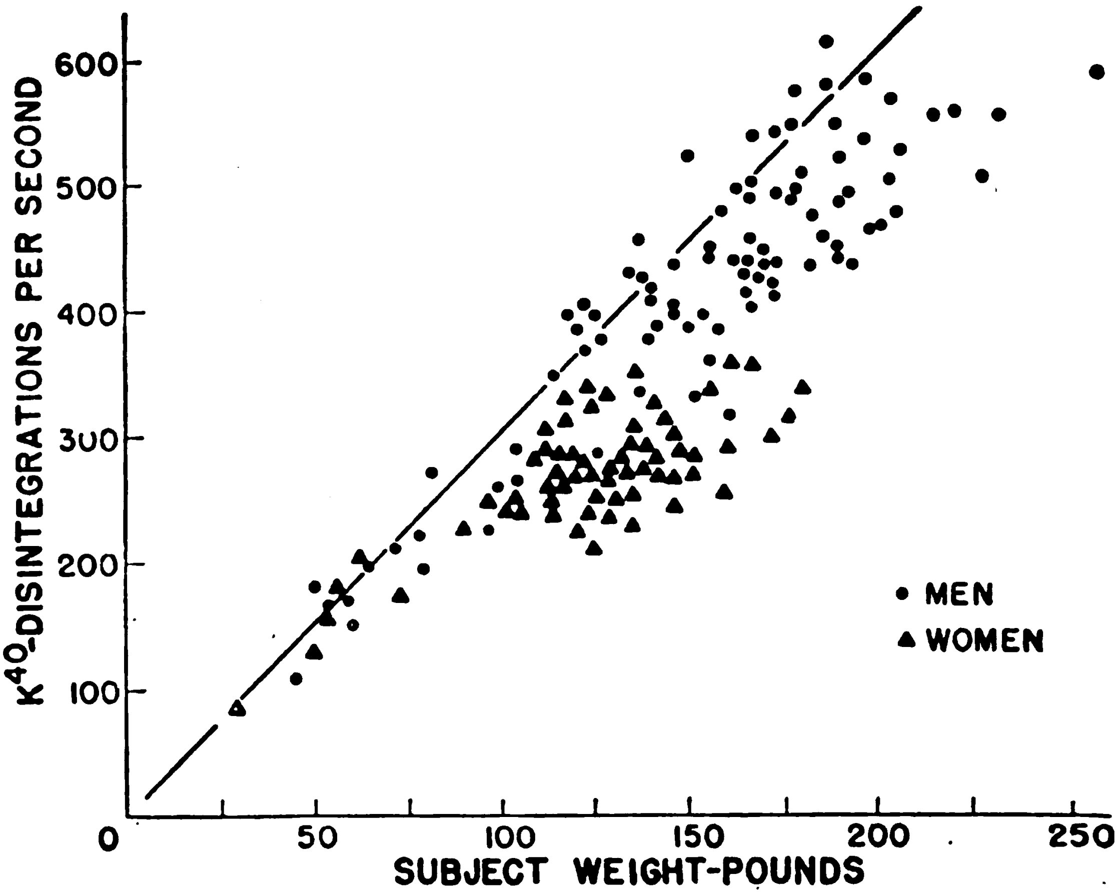


FIGURE 1.—Potassium 40 gamma activity in people as a function of gross body weight.

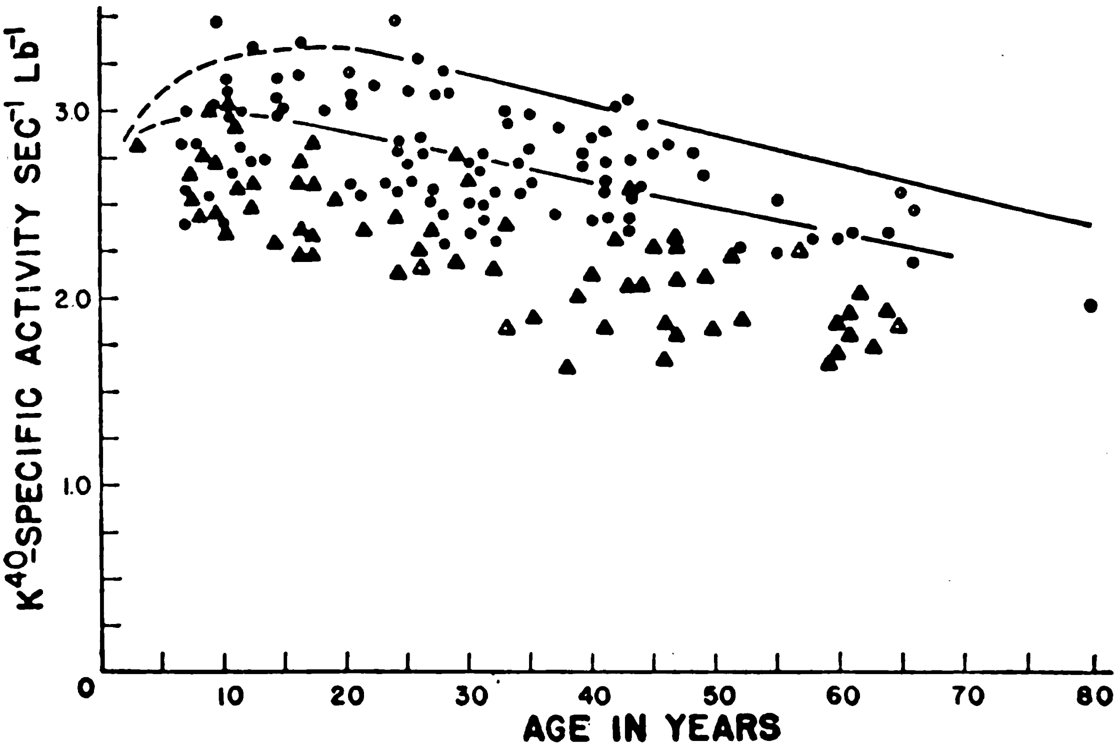


FIGURE 2.—Potassium 40 specific activity in people as a function of age.

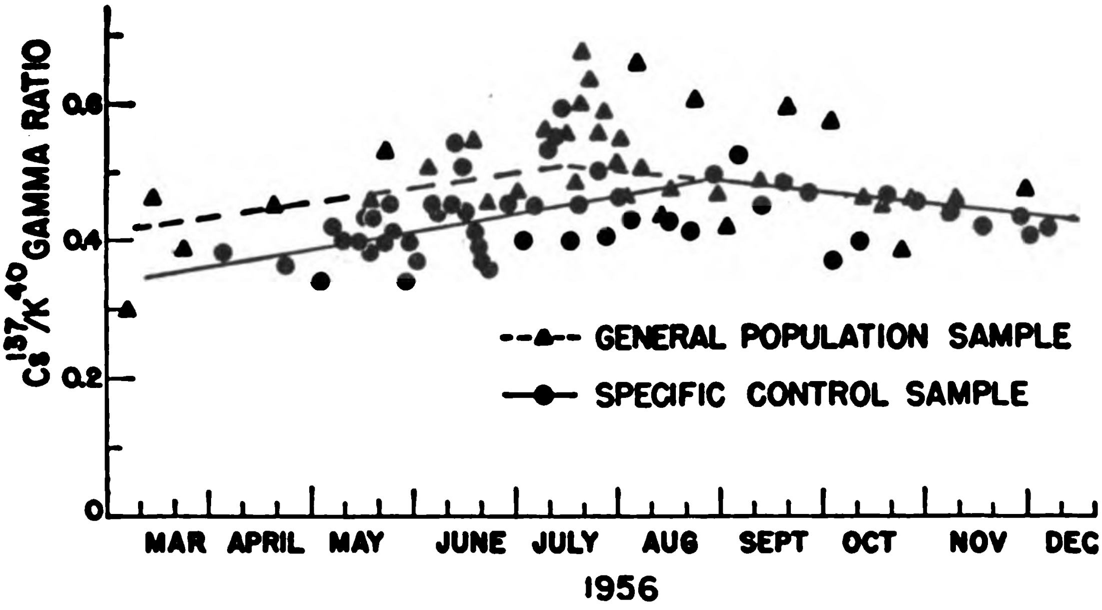


FIGURE 3.—Cesium 137/potassium 40 gamma ratio in people during 1956.

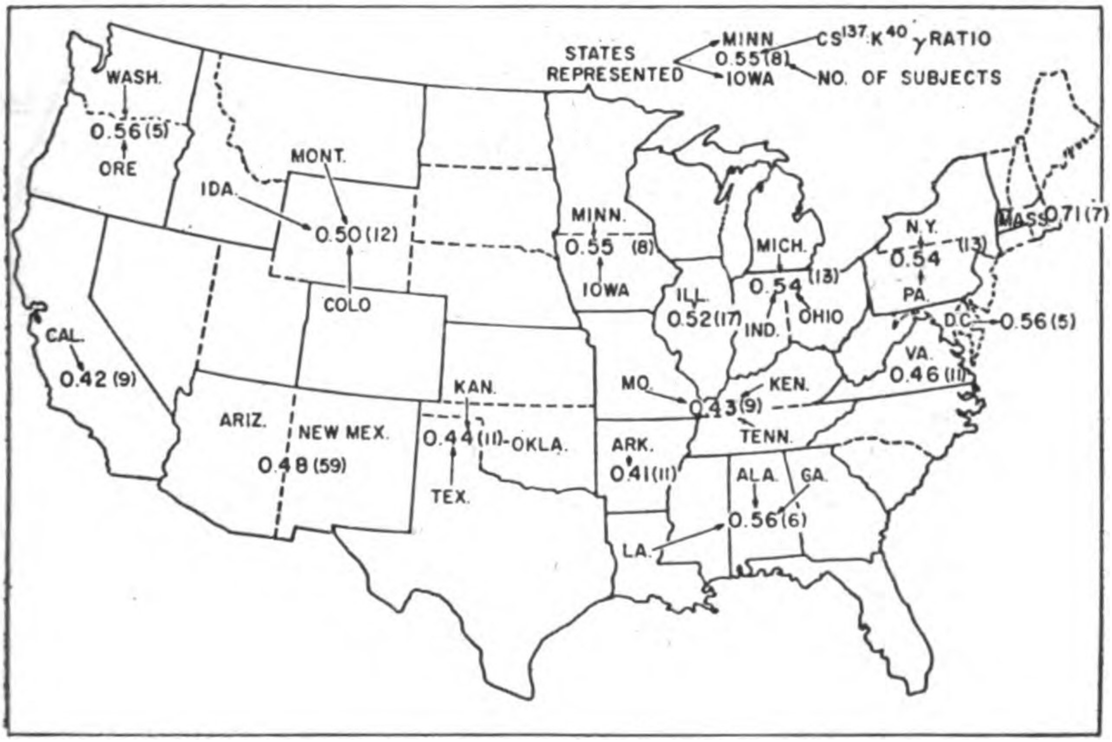


FIGURE 4.—Geographic distribution of cesium/potassium ratios in people.

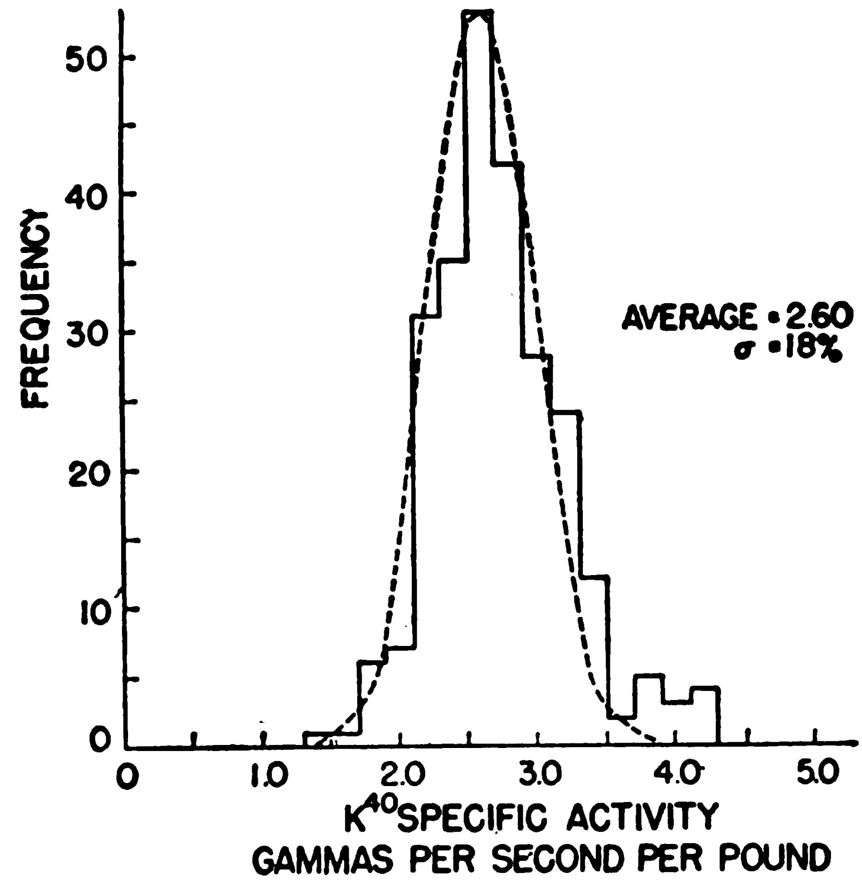


FIGURE 5.—Frequency distribution of potassium 40 specific activity.

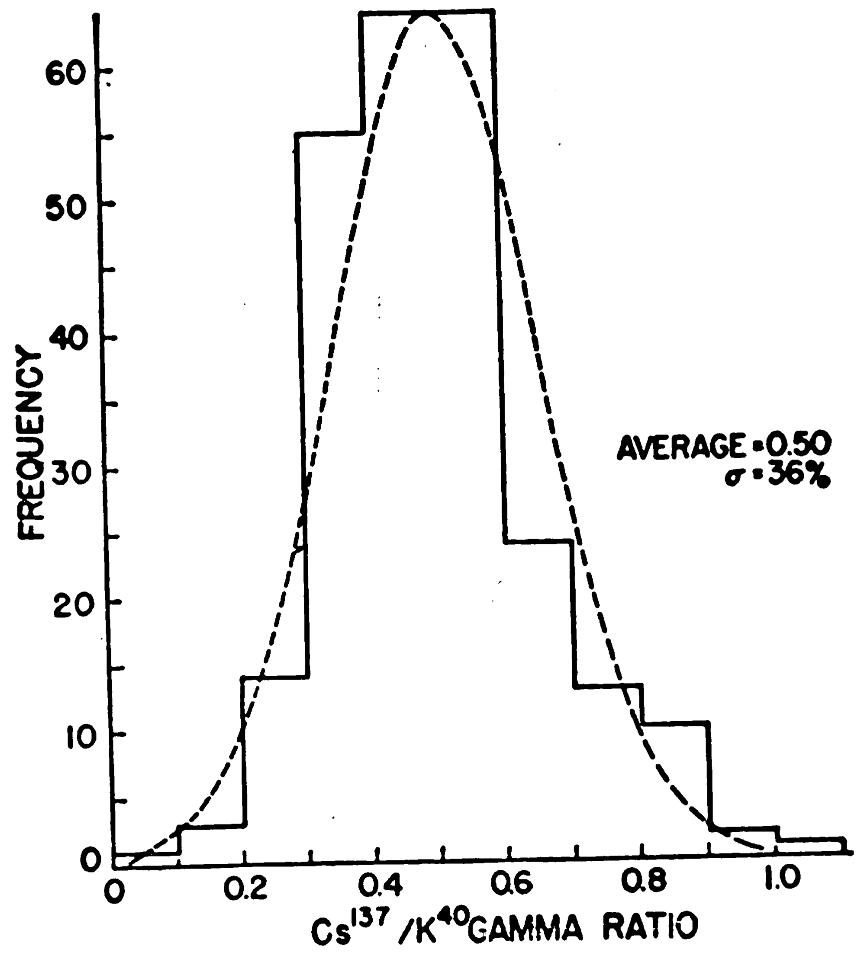


FIGURE 6.—Frequency distribution of cesium/potassium ratio.

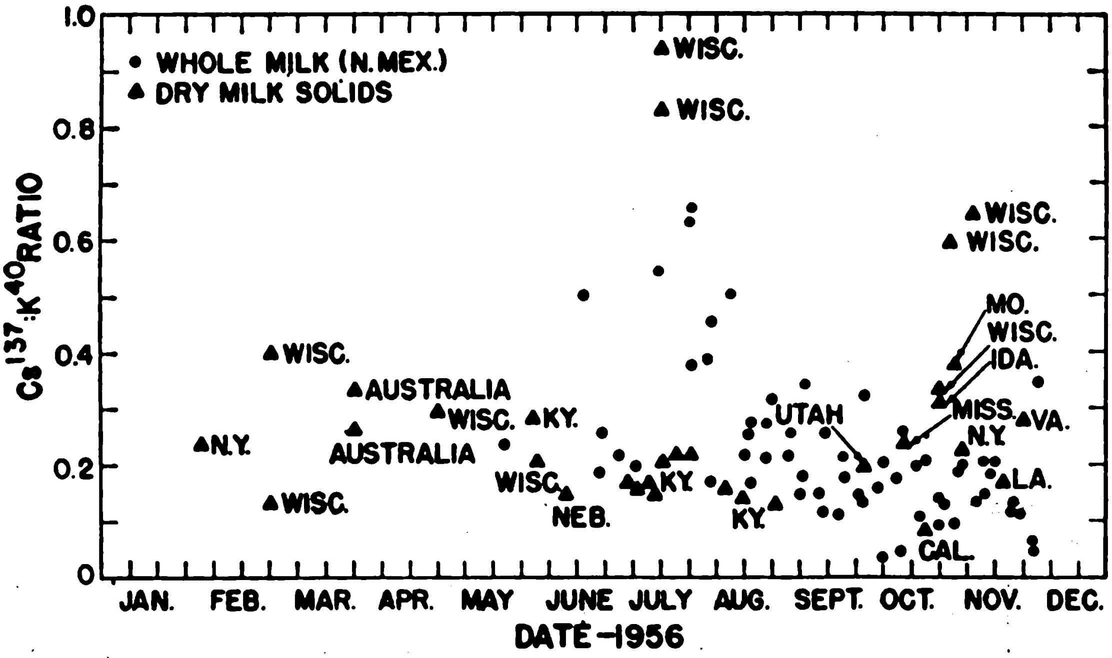
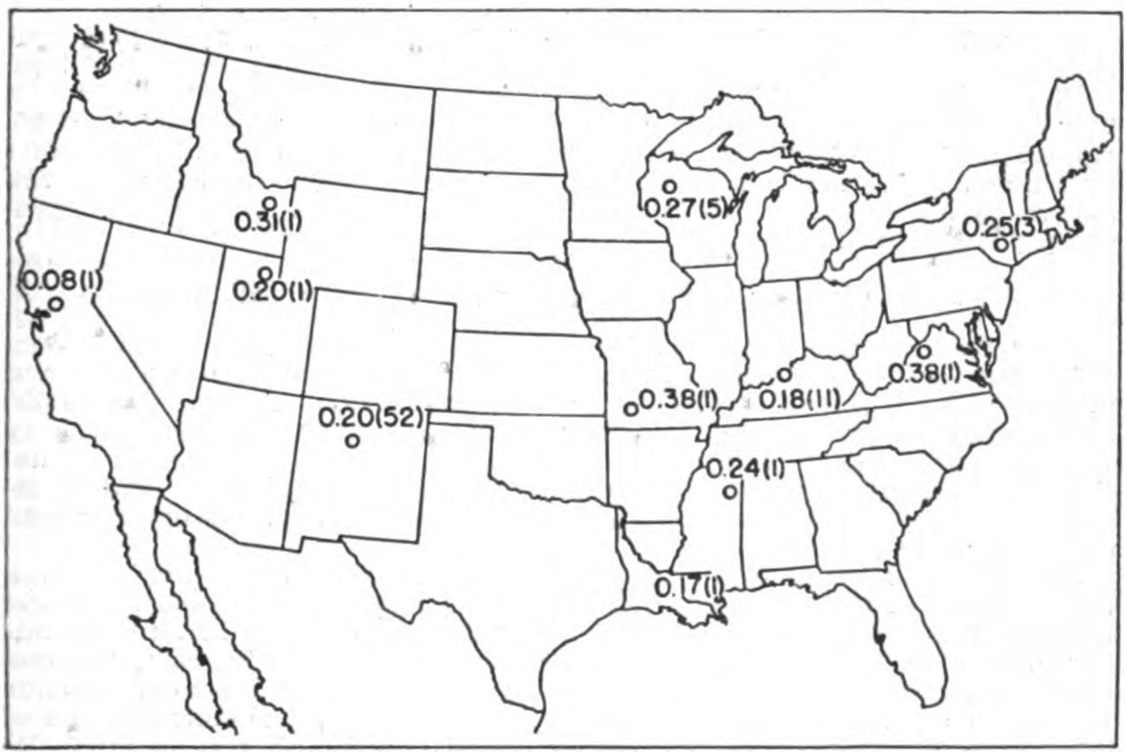


FIGURE 7.—Cesium 137/potassium 40 gamma ratio in milk during 1956.



$Cs^{137}:K^{40}$ GAMMA RATIO IN MILK
SPRING AND FALL, 1956
UNITED STATES

FIGURE 8.—Geographic distribution of cesium/potassium in milk.

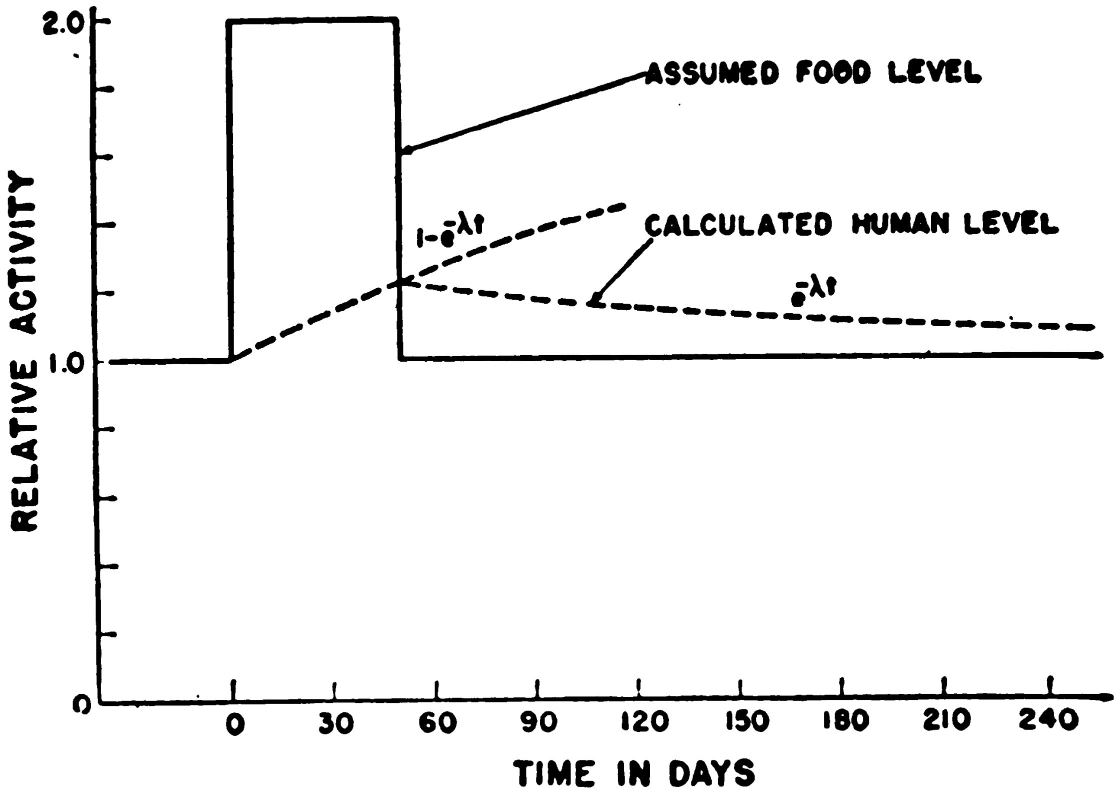


FIGURE 9.—Calculated effect of increased cesium in diet on human level.

Cesium 137 and strontium 90 also are similar in that they are soluble and closely related to potassium and calcium, respectively, which are normal base exchange cations in soil and essential constituents of living matter. In this they differ from other high-yield fission products such as zirconium-niobium 95, ruthenium-rhodium 106, and cerium 144, which have been observed in rug dirt by Miller and Marinelli at Argonne National Laboratory (11) but which are apparently not ecologically concentrated and have not been detected in the general population and in foodstuffs.

POTASSIUM 40 AND CESIUM 137 IN PEOPLE AND FOODSTUFFS

After the announcement by Miller and Marinelli of the presence of cesium 137 in people (6), an intensive program of study of this nuclide in people and in foodstuffs was begun at the Los Alamos Scientific Laboratory. Some 1,500 measurements were made; preliminary results have been reported previously (12). This article (13) summarizes the data collected during 1956. A compilation of all the primary data is being prepared as an unclassified laboratory report which will include detailed analyses of procedures, sources of error, and other information.

Measurements were made with the Los Alamos "human counter" (14), a large liquid scintillation detector that is capable of counting gamma rays from human subjects and from samples of foodstuffs up to several hundred pounds in weight with 100 percent geometrical efficiency. Although the energy resolution of this detector is quite limited compared with that of a sodium iodide (thallium) crystal, it is adequate to permit the simultaneous determination of the cesium 137 (0.661 Mev.) and potassium 40 (1.46 Mev.) gamma rays. Its ultimate sensitivity is 0.0005 microcurie of gramma activity (20 disintegrations per second) for only 100 seconds of counting time. If a 100-kilogram sample is counted, this corresponds to a specific activity of 5 times 10^{-15} curies per gram, which is far below the natural radioactivity of most materials. The natural potassium 40 radioactivity of man (about 0.013 microcurie as gamma rays) can be measured to a precision of better than 5 percent in less than 2 minutes. The cesium 137 determination has a precision of 0.001 microcurie for the same counting time.

Potassium 40 in people.—The average potassium content of the adult male is estimated to be about 133 grams (6, 15, 16) (0.19 percent of gross body

weight of the standard man), which is equivalent to about 400 potassium 40 gamma disintegrations per second.

Figure 1 gives the natural potassium 40 gamma activity of 164 representative subjects, 81 of which were reported earlier (17), plotted against gross body weight. These data show a pronounced scatter of the points to the right of a limiting line and a definite difference between males and females. Correlation of potassium 40 activity with the fat-free body weight of a select group of these subjects indicated the amount of fat to be the principal factor causing variation in apparent potassium content of the body (17). The total body potassium expressed as percentage of gross body weight will show considerable variation, therefore, depending on sex, age, weight, body type and physical activity, but it can be accurately calculated from a determination of total body water.

In figure 2 the specific activity of potassium 40 (gamma disintegrations per second and pound) is plotted against subject age. These data confirm the general decrease of potassium with age reported by Sievert (16). The solid lines indicate the probable upper limits for uncontaminated male and female subjects, respectively. Not enough children have been measured for us to be certain of the trend below age 15. The dashed lines, therefore, are estimates over this region. Deviation from these curves is an indication of possible surface contamination of individuals during periods of local fallout, since only 0.002 microcurie of hard gamma contamination is sufficient to raise the average adult from the lower to the upper limit of the specific activity distribution.

Cesium 137 in people.—Libby (2) adopted the procedure of reporting strontium 90 results as strontium 90/calcium ratios because of the metabolic similarity of strontium and calcium and to facilitate the comparison of different types of materials. Our cesium 137 results are reported as cesium 137/potassium 40 ratios for similar reasons. The principal differences in the biological behavior of the two elements can be accounted for in terms of the appropriate biological half-times. The ratios are reported as the ratio of cesium 137/potassium 40 gamma disintegrations (18).

Figure 3 summarizes the measurements of cesium 137/potassium 40 ratios in people for 1956. The triangles represent results in people from various parts of the United States (the distribution is indicated on the map, fig. 4). Each point is an average for 10 to 20 persons, and the range of values before averaging was 0.1 to 0.9. The circles are averages of measurements on a local control group of 10 laboratory personnel. The scattered high values during the period from June to September are probably the result of surface contamination from tropospheric fallout during Operation Redwing. That they were caused by surface contamination was indicated by their sudden rise and fall, by abnormally high apparent potassium 40 values during the same period, and by the fact that these high apparent potassium 40 values were reduced to normal after bathing in those cases in which remeasurement was possible.

Because of this evidence of external contamination, a line through the more reproducible lower limit of the distribution is regarded as representing the trend of internal activity. The data from the two groups agree in that they indicate a slight rise during the spring followed by a slow decline during the fall. The control group was apparently somewhat lower in the spring, but in the fall the two groups were indistinguishable.

General 1956 averages of cesium 137/potassium 40 ratios for people from various States are presented in figure 4. The results are surprisingly uniform in view of the sizable variations among individuals from the same State. Uncertainty in the averages due to small sample size precludes any deduction of fine structure until more data are available. Within the range 0.5±0.2, the cesium 137/potassium 40 ratio is essentially uniform over the United States, except during periods of tropospheric fallout.

The frequency distribution of potassium 40 and cesium 137 in the population sample is essentially normal. The potassium 40 frequency curve is given in figure 5 as a histogram with a normal error curve fitted to it. The standard deviation of the normal curve is 18 percent. The subsidiary peak outside the normal curve is caused by surface contamination during periods of tropospheric fallout.

Figure 6 shows the corresponding frequency curve of the cesium 137 data for the same population sample. Distribution is again normal, but the width is twice as great as that of potassium 40, the standard deviation being 36 percent. The smaller deviation of the potassium 40 data probably reflects control of the potassium 40 level of the body by a homeostatic mechanism that is not highly de-

pendent on intake. The cesium 137 burden, however, may vary with the dietary habits of the subject and the concentration of cesium 137 in his foodstuffs.

Libby (19) has shown that other trace elements, such as stable strontium, strontium 90 and radium 226, show normal frequency distribution curves with deviations comparable to that observed for cesium 137.

The abnormal subsidiary peak shown in the potassium 40 distribution curve is not present in the cesium data. This indicates merely that the surface contamination distorting the potassium 40 level was present in the cesium 137 channel to a proportional extent and left the cesium/potassium ratio unaffected.

Cesium 137 in milk and other foodstuffs.—Figure 7 summarizes the measurements of cesium 137/potassium 40 ratios in milk during 1956. A peak in cesium 137 activity during July, presumably woing to tropospheric fallout from Operation Redwing, is clearly visible in Wisconsin and New Mexico samples, but is absent from Kentucky milk. This observation is consistent with the path of the cloud as estimated in the United States Public Health Service air sampling network. A peak in the activity in Wisconsin milk in October is indicated also; it may be the result of a foreign test.

Data on geographic distribution of the cesium 137/potassium 40 ratio in milk are as yet scanty, but are summarized in figure 8. As with the measurements of people, one concludes that distribution is essentially uniform within the limits of the data. The uniformity, of course, applies only to the periods in which tropospheric clouds are not present. It is interesting that the two Australian milk samples (fig. 7) are in agreement with the general United States average, lending support to the assumption that the general levels are derived from the stratospheric reservoir. A sample of American dry milk produced in 1942 showed no detectable cesium 137, the cesium 137/potassium 40 ratio being less than 0.02.

Some preliminary measurements of cesium 137 in foodstuffs other than milk are given in table 1. During the spring of 1956, beef and lamb showed a ratio comparable to that of people but considerably higher than similar samples collected in the winter of 1956–57. During both periods, beef and lamb consistently ran higher than pork, which might be expected from the differences in grazing and feeding habits. One sample of dried blood collected in April 1952 showed a ratio less than one-third that of samples collected during the winter of 1956–57.

DISCUSSION

Measurements of present levels of cesium 137 in people indicate that it is of little significance in the potential hazard of radioactive fallout from weapons testing programs. The present average cesium 137/potassium 40 total distintegration ratio is about 0.05. Taking into consideration their respective energies, the radiation dose from present levels of cesium 137 is only one-twentieth of that from natural potassium 40, or about 1 milliroentgen per year. This is about 1 percent of the average total natural radiation dose and less than 10^{-3} of the dose of cesium 137 given in the recommendations of the International Commission for Radiological Protection as the maximum permissible level for the general population (20). Interest in cesium 137, therefore, centers on its potential usefulness in the study of fallout mechanisms.

A rough quantitative comparison of the present average strontium 90 and cesium 137 levels in people is of interest. According to Libby (3), the strontium 90 level in children is about 0.001 microcurie. A fractionation factor of about 10 against strontium between primary fallout and human bone is indicated by the stable strontium data (21) (that is to say, the strontium/calcium ratio in soil is 10 times the strontium/calcium ratio in bone), but cesium can be assumed to be quantitatively absorbed by both cow and man. Although strontium will continue to accumulate because of its long biological half-time, the effective accumulation time for cesium will be limited to some 200 days. If stratospheric fallout is assumed to have begun with Operation Castle (1954), strontium 90 has been accumulating for some 2 years, and this factor will cause it to exceed cesium 137 by $2\times365/200$, or 3.6. Finally, the relative activity yield in the fission process is 1.27 in favor of cesium (assuming fission yields of 0.0510 and 0.0620 for the mass 90 and mass 137 chains and half lives of 27.7 years for strontium 90 and 26.6 years for cesium 137). The overall factor is then $10\times1.27/3.6$, or about 3 for cesium 137, and the estimated level based on a strontium level of 0.001 microcurie is 0.003 microcurie. Considering the crudity of the several approximations, this is in surprisingly good agreement with the observed average of 0.005 microcurie.

TABLE 1.—*Radioactivity in foodstuffs*

Sample	K-40 specific activity (disintegration/sec. lb.)	Cs-137/K-40 ratio	Sample	K-40 specific activity (disintegration/sec. lb.)	Cs-137/K-40 ratio
Meat, spring 1956:			Flour, spring 1956:		
Beef rounds	3.84	0.53	High-altitude wheat (Colorado)	1.30	0.09
Lamb, dressed carcass	3.83	.81	Bleached, enriched (A)	1.70	.32
Pork, fresh hams	3.52	.30	Bleached, enriched (B)	1.49	.27
Pork, loins	3.23	.19	Whole wheat, graham	7.00	.11
Meat, winter 1956–57:			Potatoes, spring 1956:		
Beef, sirloins	2.75	.15	Colorado	7.82	<.06
Lamb, dressed carcass	3.67	.16	Idaho	6.52	<.06
Pork, loins	3.55	.10	Vegetables, spring 1956:		
Pork, loins	3.26	.07	Lettuce	2.34	<.07
Dried blood:			Cabbage	3.20	.12
Illinois, Apr. 1952	9.20	<.07	Carrots	6.82	<.03
California, winter 1956–57	7.30	.25	Fruits, spring 1956:		
Minnesota, winter 1956–57	5.40	.25	Tomatoes	3.81	.03
Texas, winter 1956–57	5.90	.18	Oranges	2.10	.38
			Grapefruit	3.30	.25
			Watermelon	3.75	<.03
			Coffee, spring 1956	30.00	<.06

TABLE 2.—*Calculated cesium 137 intake based on per capita food consumption. Diet was based on Consumption of Food in the United States, supplement for 1954 (22)*

Source	Consumption (lb./mo.)	Cs-137 concentration (mμc./100 lb.)	Cs-137 intake (mμc./mo.)
Dairy products (as dry-milk solids)	5.8	14	0.81
Meats	11.4	3.3	.38
Flour and cereal products	13.0	1.0	.13
Vegetables	16.8	(1)	?
Citrus fruits	3.2	2.4	.21
Potatoes	8.8	(1)	?
Total			1.5

[1] Not detected.

Measurements of cesium 137/potassium 40 ratios in milk during 1956 (fig. 7) indicated peak activities resulting from periods of tropospheric fallout. The relative effect of such increases in foodstuffs on the cesium 137 level in people can be estimated from the simple model shown in fig. 9. A step function change in the foodstuff level will be followed by a $(1-e^{-\lambda t})$ change in the population level (where λ is the biological elimination rate), and a new equilibrium value will be reached only after an elapsed time of the order of 1 year. If the foodstuffs return to their previous value before equilibrium is attained, the population level will cease rising and will decay back to its previous value with a halftime corresponding to the biological elimination rate.

This model can be applied to the situation during July and August, when the level of cesium 137 in milk rose by about a factor of 3. Since not enough data are available to define completely the shape of the peak, and since milk values are used as representative of all foodstuffs, the actual peak can be replaced with a step function of the same approximate area. This gives a rise of about 2 times "normal" for a period of 50 days. In this case, the maximum rise in the population level, predicted on the basis of the model in figure 9, is 20 percent. Using the average value of the cesium 137/potassium 40 ratio for the control subjects in the spring of 1956 (fig. 3) of 0.4, their calculated ratio 6 months later is 0.5. The observed summer maximum average was 0.48, in agreement with the model.

An estimate of the biological halftime of cesium 137 in the chronically exposed case was obtained by counting a large urine sample representing 52 man-days of excretion. The sample showed 408 disintegrations per second of potassium 40

(136 grams of potassium) and 40 disintegrations per second of cesium 137. Assuming an average body burden of 0.005 microcurie of cesium 137 for the 6 subjects who contributed urine samples, the excretion rate is 0.004 per day, which corresponds to a halftime of some 180 days if the excretion is exponential and entirely urinary. If fecal excretion is 25 percent of urinary, the halftime would be 145 days. This is in agreement with the biological halftime of 140 days observed on volunteers who ingested 1 microcurie of radiocesium (9).

Using Bureau of Agriculture statistics for food consumption per capita in the United States (22) and our preliminary values for the average cesium 137 content of foodstuffs, the dietary intake of cesium 137 can be estimated (table 2). On the basis of these data, it appears that milk contributes about 50 percent and meat about 25 percent of the cesium 137 found in the body. The excretion rate of cesium 137 can also be estimated from these intake data. This method is only an approximation because of uncertainties in diet and in the average cesium 137 level in the various dietary components. According to the data in table 2, the turnover rate is of the order of 1.5 millimicrocuries per month, compared with the observed value of 0.6 millimicrocurie. Part of the discrepancy may result from using retail weights in computing the diet with no allowance for wastage and loss of minerals in cooking, but the principal source of error is probably the inadequacy of our knowledge about cesium in foodstuffs. For comparison, a similar computation was made for potassium (table 3). The calculated potassium intake is about 3 grams per day, while the observed urinary excretion was 2.6 grams per day. Elkinton and Danowski (23) reported potassium turnover as falling in the range of 2 to 6 grams per day.

TABLE 3.—*Calculated potassium intake based on per capita food consumption*

Source	Consumption (lb./mo.)	Potassium: Content (g./lb.)	Potassium: Intake (g./mo.)
Dairy products	5.8	6.0	35
Meats	11.4	1.2	14
Flour and cereal	13.0	.5	6
Vegetables	16.8	1.0	17
Citrus fruits	3.2	1.0	3
Potatoes	8.8	2.0	18
Total			93

While the spring 1956 average value for the cesium 137/potassium 40 ratio in milk was 0.25, the average in people for the corresponding period was 0.4. This difference may be explained on the basis of the longer holdup time of cesium in the body as compared with potassium. If q_{cesium} is the amount of cesium in the average daily diet, and $q_{potassium}$ is the corresponding amount of potassium, then $q_{cesium}/q_{potassium}$ is the cesium/potassium ratio for the average diet. The milk ratio can be used since it is the most important single factor and is the only one known with any accuracy. The equilibrium amounts of cesium and potassium in the body, on the basis of the simplest model, will be given by the product of $q\tau$ for each element, where τ is the mean life of the element in the body (24). For cesium, τ has been determined to be 200 days; τ for potassium can be estimated from our data on the potassium content of normal urine as about 58 days. Therefore, cesium should be concentrated relative to potassium by a factor of 200/58, or 3.4. If the average diet ratio is 0.23, the predicted ratio in people is about 0.8. This is too high by a factor of 2.

Libby (4) has estimated stratospheric injection by Operation Redwing at about 6 megatons of fission products in addition to the 18 megatons left from the previous operations. This would imply a 30-percent increase in the fallout rate from the stratospheric (worldwide) component after the tropospheric component is gone. A comparison of the spring and autumn milk averages indicates no detectable increase in the fallout rate. The spring sampling was inadequate; hence there is considerable uncertainty about the proper average. However, it would appear that, if anything, the cesium levels in the fall were lower. This may be a seasonal variation resulting from the change from pasture to hay feeding of the dairy herds, which would conceal possible small increases.

SUMMARY

Measurements of the cesium 137 content of people and of foodstuffs indicate that this nuclide is unlikely to be a decisive factor in the long-term hazards from weapons testing and reactor waste disposal. The amount of cesium 137 now present in the population of the United States averages 0.006 microcurie and shows no marked dependence on geographic location. The average radiation dose received from cesium 137 is one-twentieth of that received from natural radiopotassium and 1 percent of the average total dose from all natural sources. Because of the short biological half-life of cesium of about 140 days, it does not accumulate in the body as does strontium 90. The study of the distribution of cesium 137 is being continued to furnish information on the mechanisms of the fallout process and provide a measure of the rate of fallout and of stratospheric storage.

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13. This work was performed under the auspices of the U. S. Atomic Energy Commission. We are grateful to a number of persons who assisted in various phases of this program. We are particularly indebted to L. D. Marinelli and C. E. Miller of Argonne National Laboratory for helpful discussion and for their generosity in making measurements of interest to us on their crystal counter. Their assistance aided materially in the initial development of this program. J. W. Ballow supplied most of the foodstuff samples, and R. J. Remaley of the American Dry Milk Institute has been very helpful in the procurement of samples of dry milk. H. E. Gilbert of the Los Alamos Scientific Laboratory set up the punched card system used for electronic data processing.
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24. $\tau=1/\lambda=t\frac{1}{2}/0.693$, where τ is the mean or average time the nuclide remains in the body, λ is the elimination rate, and $t\frac{1}{2}$ is the time necessary to remove half the body burden.

Statement Submitted to the Joint Committee on Atomic Energy by L. D. Marinelli[1] and J. E. Rose,[2] Radiological Physics Division, Argonne National Laboratory, Lemont, Ill.

TOPIC IX. OCCURRENCE OF CS-137 IN THE ATMOSPHERE, BIOSPHERE, AND ITS UPTAKE AND BEHAVIOR IN MAN

The fission product Cs-137 is produced with a yield of about 6 percent and it has a half life of about 27 years. The general characteristics of its distribution and behavior in mammals, as reported by several authors (1–4), indicates only a partial qualitative similarity to potassium. Important from our standpoint is the fact that cesium is excreted by humans at a rate lower than potassium. This leads to a Cs/K ratio in vivo which is from 2 to 3 times the ratio in the ingested food.

Because of its gamma-ray emission, Cs-137 can be measured in the living animal and in bulk material without recourse to lengthy chemical analysis.

To make these measurements, it is necessary to shield both instrument and subject from the radiation emitted by ordinary building materials. This is done by performing the tests in an 8 by 8 by 6 foot room with 8-inch steel walls, weighing 60 tons. This room consists of a bolted frame of angle beams upon which one-quarter inch plates of 12 to 26 inches width are placed in staggered sequence on all sides in order to avoid continuous cracks in the walls. The side plates are held in place by clamping them together between the frame and appropriately placed angle irons.

Gamma-ray radiation emitted by the subject impinges on an 8 inch by 4 inch NaI crystal; the electrons liberated therein produce scintillations which are amplified by a photomultiplier tube and registered, according to their sizes, by a 256-channel analyzer. From the scintillation spectrum it is possible to identify the energy of the gamma radiation (hence the radioelement responsible for it) an dits intensity (hence the amount of material involved). Presently this apparatus has a sensitivity greater than 10^{-9} curies of the gamma emitters under discussion in the intact human subject.

In the summer of 1955, at the Argonne National Laboratory, measurements of the total body gamma-ray activity of members of our staff, visitors from various parts of the country and from overseas, local medical students, etc. (5), disclosed the presence of this radioelement in all of the test subjects. Since then, continual tests on a group of 12 people, has shown an increase in the human burden by a factor of about 2 up to the spring of 1956, and a constant value thereafter, corresponding to about 3.2×10^{-11}C of Cs-137 per gram of potassium (fig. 1). Contrasted to the findings for Sr-90, children do not exhibit high concentration per unit weight.

No correlation between Cs-137 content and geographic origin of the subject was noted (table I). On the other hand, the dependence on the dietary habits of the individual (fig. 2) became evident after a study of the Cs-137 content of food and water. These revealed that bovine meats, milk and milk products constitute the main routes of intake (fig. 3). Subsequent confirmation of these findings on larger representative samples of people and foodstuffs have been obtained at the Los Alamos Scientific Laboratory (6). The observations to date

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are consistent with the concepts of (*a*) stratospheric storage, (*b*) constant deposition on grazing lands, (*c*) uptake by cattle, and (*d*) transmittal to man.

Other relatively abundant and long-lived fission products, i. e., Ce–144—Pr–144 (290 day), Zr–45—Nb–95 (63.3 day), and Ru–106—Rh–106 (1 year), easily detectable by our technique in laboratory air, dust, sweepings from house carpets (fig. 4) and soil (7) are not present in the intact mammal in measurable quantities. These findings are consistent with previous observations on their low intestinal absorption following oral intake by laboratory animals (3).

In its present concentration, Cs–137 contributes on the average less than 0.3 mrad to the yearly dose of over 150 mrads which a human being is reported to absorb from natural sources of radiation (fig. 1).

Because of its relatively short life in the cow and of its reputed unavailability to the roots of some plants,[8] the concentration of this radioelement in milk is likely to serve as an excellent indicator of average rate of fallout over milk sheds. Since we can measure directly its presence in the living human we need not rely on theoretical predictions as to the possible individual variations under various conditions. Thus, only a factor of 6 separates the lowest values found in oriental subjects (whose diets are practically devoid of cattle products) to the highest found in the United States of America in an individual on a milk diet.

Pertinent to this discussion and to item X of the agenda are our recent findings on some inhabitants of the Marshall Islands which were measured in our facility by Dr. C. E. Miller. The scintillation spectra are shown in figure 5, and the body contents are included in table I. It should be noted that subject No. 10 is a control living in Majuro Island which did not experience unusual fallout. The next four subjects were inhabitants of Rongelap removed more or less permanently from that island to Majuro Island because of heavy fallout. Their content of Cs–137 is about 2 or 3 times that of the average United States citizen. The reason for this cannot be stated at this time but consumption of coconuts (reputed to acquire Cs) may be implied. The presence of Zn–65 in their body is due to contamination of seafood.

The highest contents of both Cs–137 and Zn–65 were found in subjects Nos. 5 and 18 who were removed temporarily from the island of Uterek because of heavy fallout and returned there after appropriate decay of the external radiation. It is obvious that they represent burdens likely to be acquired by living in zones of relatively high levels of contamination. Yet, despite these circumstances the increased dose rate of radiation to which they are exposed is only a fraction of the normal background of 100 to 160 mrads per year.

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(NOTE.—See middle of p. 745 for a remark concerning this statement.)

TABLE I.—*Gamma ray activity of human beings*

Country	Subject	Date	Cesium 137			Zinc 65		Natural Potassium
			µµc/gK	mµc/man	mrads/yr.	mµc/man	mrads/yr.	mrads/yr.
United States	Average	1956	34.0	4.8	0.29	--------	--------	Average value for all humans 25-40.
England	T	May 16, 1956	33.0	4.7	.28	--------	--------	
Do	R	July 13, 1956	35.0	4.9	.29	--------	--------	
France	J	Sept. 21, 1956	33.0	4.6	.27	--------	--------	
Denmark	F	Oct. 30, 1956	26.0	3.7	.22	--------	--------	
Sweden	N	Nov. 29, 1956	32.0	4.5	.27	--------	--------	
Australia	P	Mar. 27, 1957	50.0	7.0	.42	--------	--------	
India	Vo	Dec. 18, 1957	18.9	2.6	.16	--------	--------	
Do	Va	do	20.8	2.9	.17	--------	--------	
Japan	S	July 26, 1956	24.5	3.4	.20	3.2	0.02	
Indonesia	S	Aug. 10, 1956	13.9	2.0	.12	2.1	.01	
Do	M	do	8.5	1.2	.07	--------	--------	
Marshall Islands	10	Apr. 5, 1957	65.0	9.1	.55	30.0	.19	
	6	do	69.0	9.7	.58	73.0	.46	
	9	do	73.0	10.0	.61	30.0	.19	
	4	do	79.0	11.0	.67	30.0	.19	
	7	do	95.0	13.0	.80	62.0	.39	
	5	do	1,600.0	230.0	14.0	480.0	3.0	
	8	do	2,700.0	380.0	23.0	230.0	1.5	

Source: NBS Handbook 52—Maximum Permissible Levels: Zn-65=430 µcs; Cs-137=90 µcs.

FIGURE 1

Cs^{137} TRENDS IN HUMANS

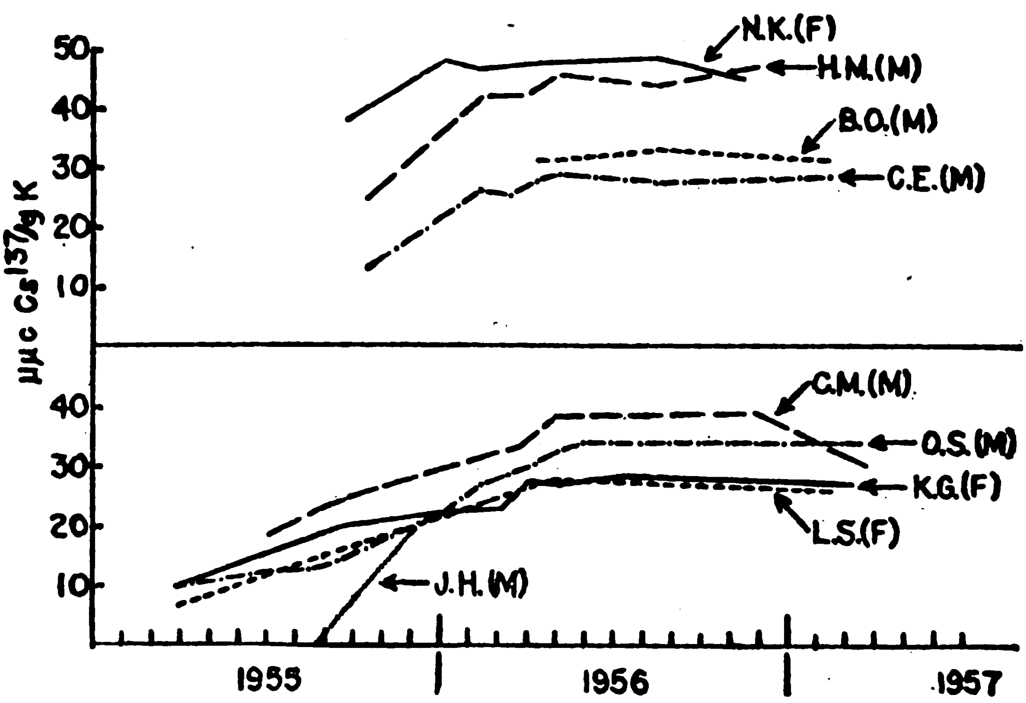


FIGURE 2

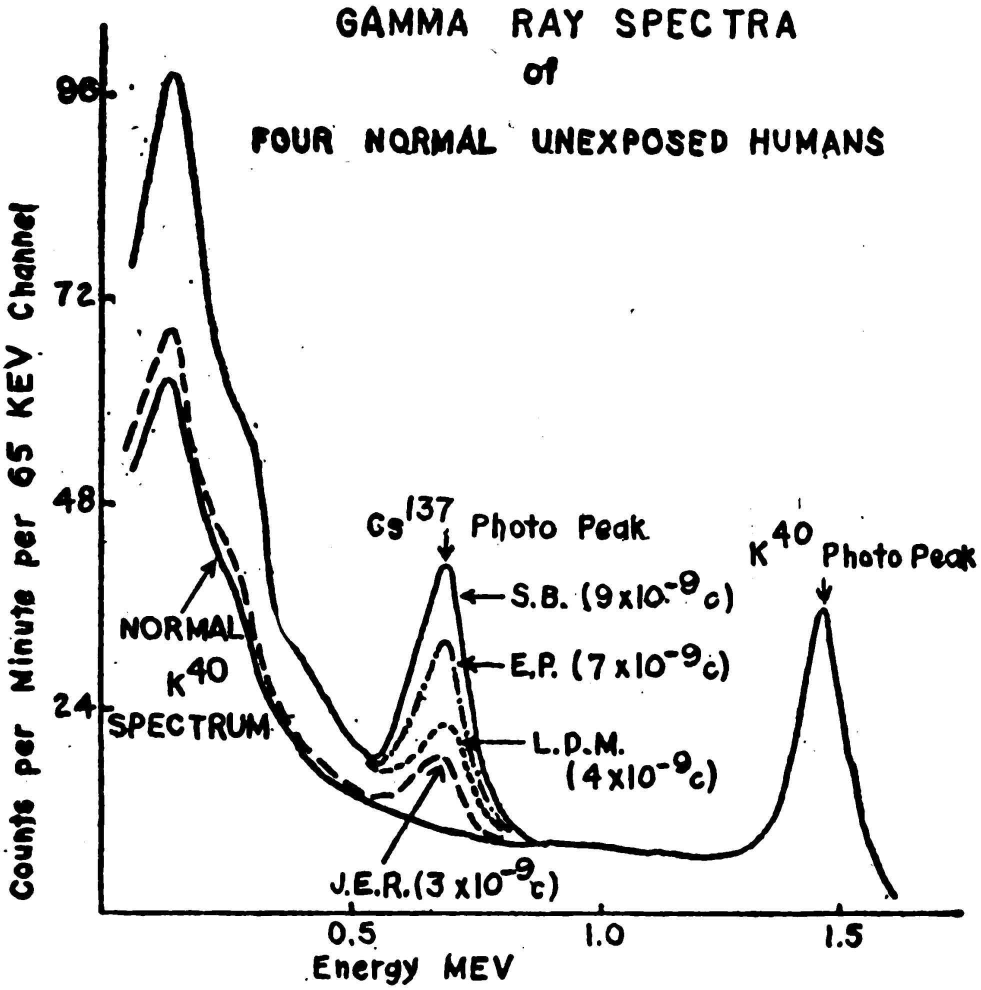


FIGURE 3

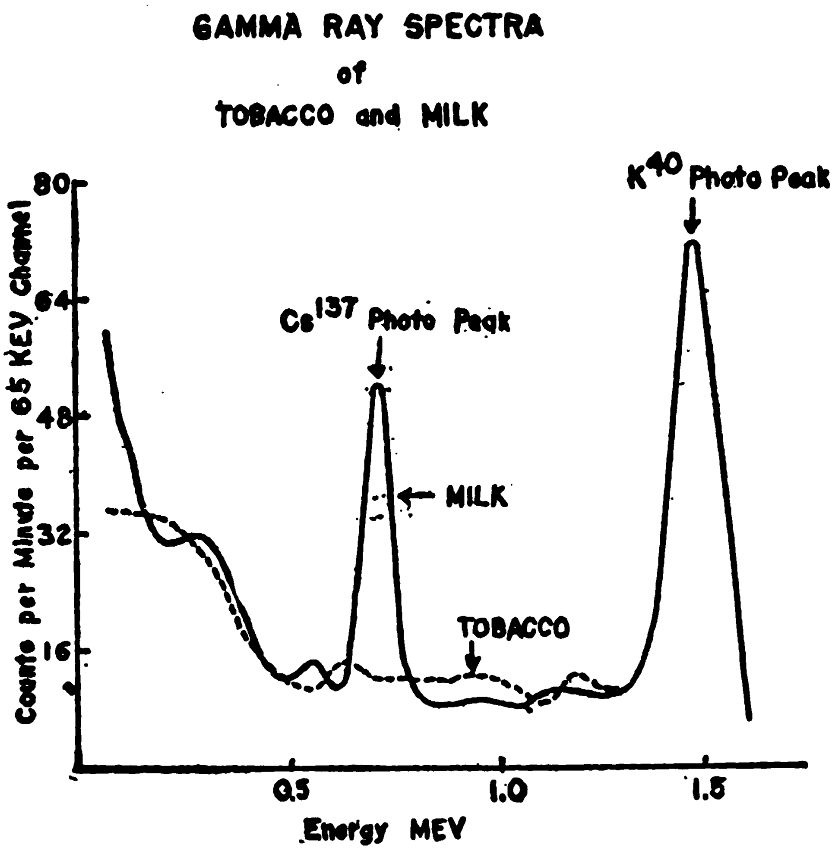


FIGURE 4

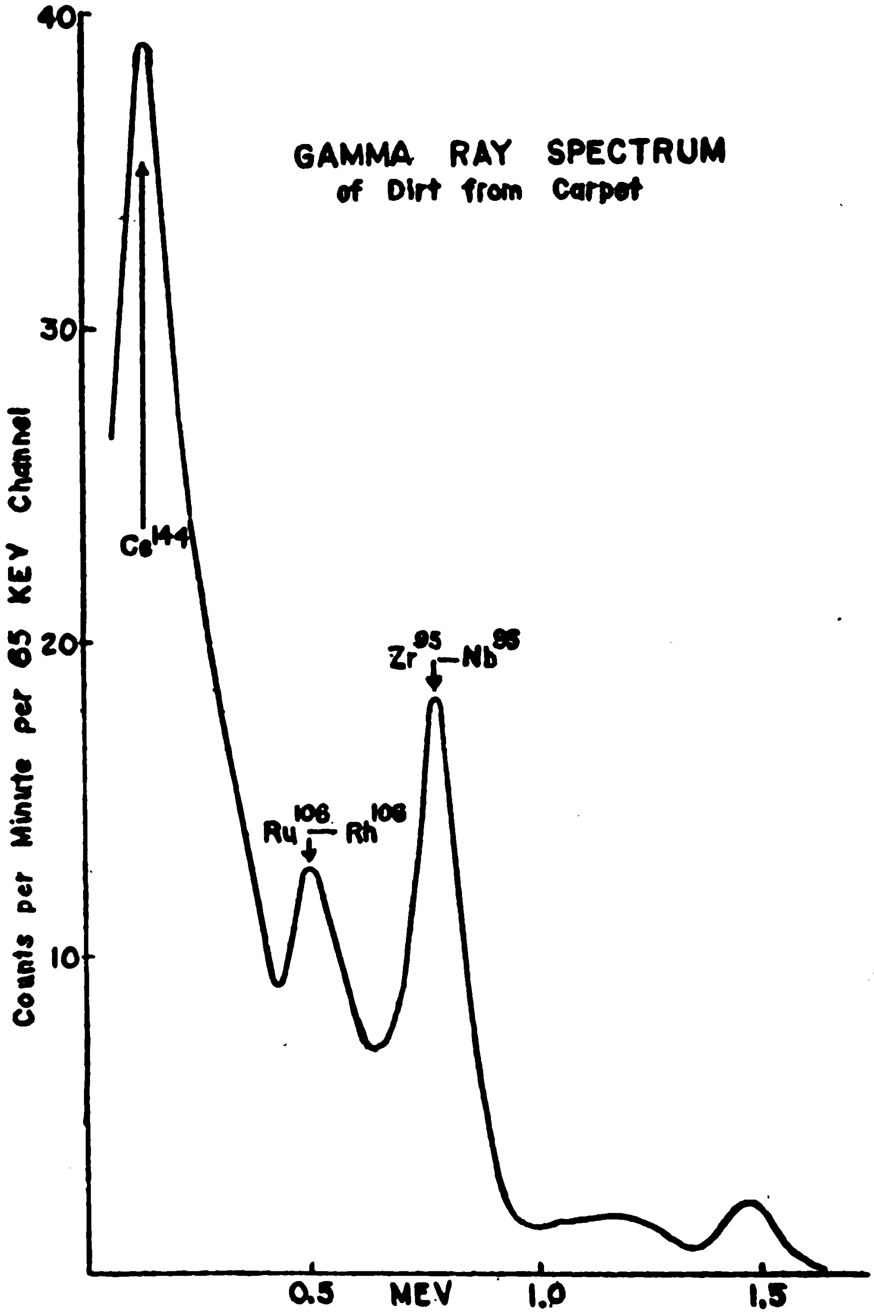
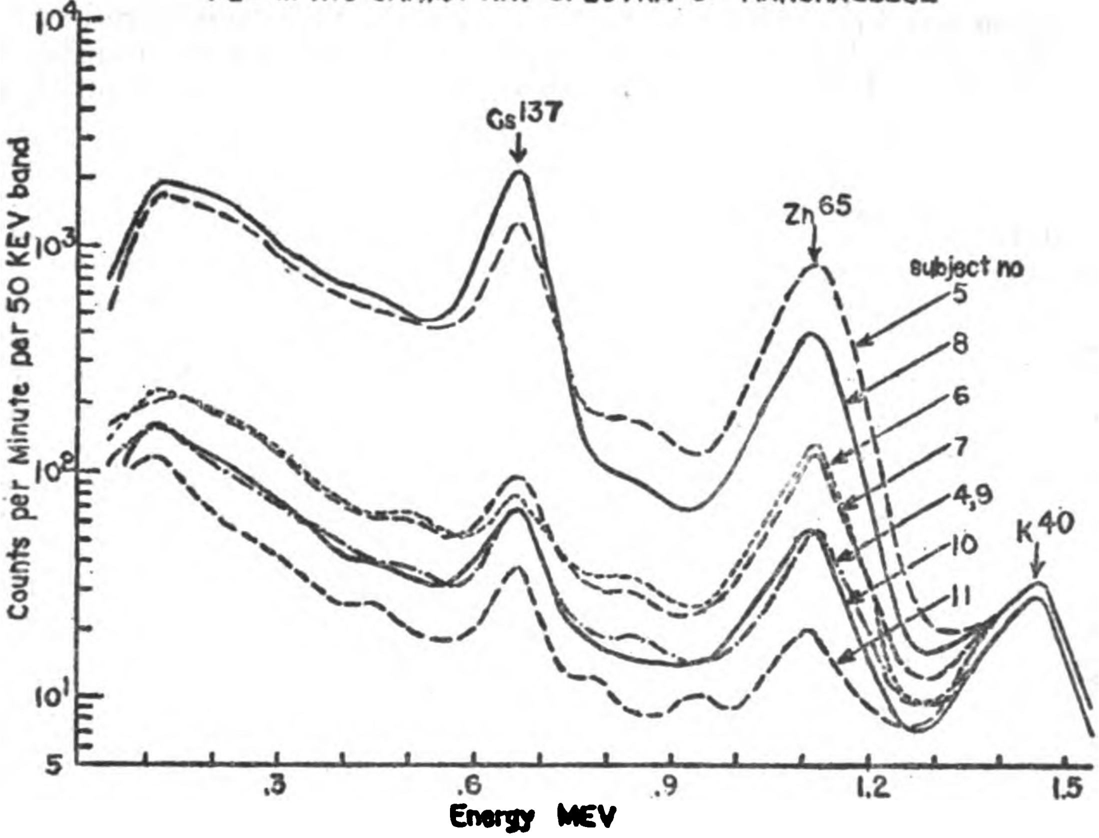

GAMMA RAY SPECTRUM
of Dirt from Carpet
Counts per Minute per 65 KEV Channel
40
30
20
10
Ce144
Ru106 — Rh106
Zr95 — Nb95
0.5
MEV
1.0
1.5

FIGURE 5

NET in vivo GAMMA RAY SPECTRA OF MARSHALLESE



Senator ANDERSON. Dr. Kulp, Dr. Eisenbud, and Dr. Neuman, do you and Colonel Hartgering want to get into some questions here, back and forth, that would be helpful to all of us? Dr. Langham, we would like to have you in it also.

Mr. Neuman, do you want to kick off on any comments you may have on the afternoon presentation?

DISCUSSION BY DR. J. L. KULP, MERRIL EISENBUD, DR. WILLIAM F. NEUMAN, DR. WRIGHT LANGHAM, AND COL. JAMES B. HARTGERING

Dr. NEUMAN. I would rather sandbag, if I may.

Mr. RAMEY. It might be desirable if Dr. Neuman could sort of state his case. Some of the members were not here and Dr. Kulp was not here at the time either.

Dr. NEUMAN. As a brief summary, I think it best to say that, in my opinion, the very best evaluation of future levels of bone are those calculated from our equilibrium data on natural strontium because this involves only one assumption; strontium behaves like strontium.

It is also my opinion that the natural strontium data in England and the bulk of the experimental data available in this country indicate that the overall discrimination from ground to bone is about a factor of 8. With this number, one has a fixed relationship between ground level and bone level. If we choose a certain maximum level to be permitted in human bone, we automatically fix a maximum level that can be permitted on the ground. With this number one can calculate the maximum rate at which testing can produce fission

products. The testing rate can be 2½ percent of the permissible ground levels.

Using a rather arbitrary set of numbers, the maximum permissible level of 50 sunshine units, which is one of the several levels that have been suggested, the test rate comes out to be a rather small number of the order of 2 megatons of fission equivalent per year.

I think that is a fair summary.

Senator ANDERSON. I think what perplexes a great many of us is that Dr. Langham wrote down a great number of figures and they all were pretty much in agreement—2.5, 3.1 at Los Alamos, 4.1 from Dr. Eisenbud, 3.5 from the milksheds—those figures are very close, very accurate, and apparently we have come to some sort of agreement.

Do you agree that it is going to take a hundred years of testing to get to the point where there is some danger to it if we continue at just the present level?

Dr. NEUMAN. I don't see how anyone could make a prediction concerning how long it would take because one has to assume a test rate.

Senator ANDERSON. I tried to say at the present level of putting fission products into the atmosphere. I am trying to get some fixed term if I can use it. If that is not a correct one I am sure Dr. Langham can give me a better one.

Dr. NEUMAN. I am not clear what present level of testing has been assumed. I take it to be based on measurements up to the fall of 1956.

Dr. LANGHAM. It has averaged roughly 10 megatons for 5 years.

This does not include anything that the Russians and British have done in the last few weeks.

Senator ANDERSON. I think that is useful. Can we all use that same figure and say we will assume, regardless of whether it is accurate or not—let us assume it is accurate, and I think it is probably very close—that we have been putting 10 megatons of fission products into the atmosphere each year for the last 5 years. Suppose we continue at that clip for the next 20 years, Dr. Neuman would you think that we had reached the maximum permissible level after 25 years or something of that nature?

Dr. NEUMAN. I should think it would be of the order of 25 years. Actually it would be a million years before you achieve true equilibrium. But for practical purposes, 25 years would be a reasonable number. It depends upon the MPC.

Mr. EISENBUD. 50 would probably be best.

Dr. NEUMAN. I agree, if the MPC is taken as 100 sunshine units.

Senator ANDERSON. Dr. Kulp, what do you think.

Dr. KULP. I don't think I am competent to say when there is a hazard. This is what you must get into next week. As far as the levels are concerned, it looks like there is only about a factor of 2 or 3 difference in the way Dr. Neuman and I calculated this thing. He used 50 instead of 100 as the safe level, and he used a factor of 10 from the soil to bone.

Dr. NEUMAN. Eight.

Dr. KULP. Yes; eight. I did not base it on the soil because I do not believe that the strontium 90 is ever going to be homogeneously distributed all the way through the soil, which is the condition you must have to get his 8 and 10 figure. This is based essentially on dividing

the milk value by 2. I end up with a practical soil to bone value of closer to 20. You can take your choice on these two things. That is the way they are derived. It depends on whether or not the strontium 90 becomes homogenized throughout the whole earth column.

Senator ANDERSON. Dr. Eisenbud.

Mr. EISENBUD. Mr. Chairman, I would like to supplement the remarks I made earlier today. I predicted a maximum of 5 micromicrocuries per gram from the tests to date. If we assume that the testing rate is going to continue as it has in the last 5 years, then the maximum instead of being 5 would be about 40, sometime after the turn of this century. If I superimpose a factor of 3 that Dr. Neuman used in order to allow for individual biological variation—and I am not sure this is necessary—then I arrive at a figure of 120 micromicrocuries per gram. This suggests that if we are going to continue testing until the year 2020 and if we are going to limit the maximum to Dr. Neuman's figure of 50 micromicrocuries per gram, then we are going to have to reduce the testing rate to one-third of the rate for the past 6 years.

Senator ANDERSON. You now say, if I can try to tell you what is in the minds of some people, that if we can continue the test to the year 2020 and if these other factors continue, and I am not trying to bind anybody to them, then we will have to cut down the testing by a factor of 3. That brings it down to 3 megatons of fission products to be discharged each year. We say if we are going to continue as we are now going, when will we reach an extremely dangerous position? Will that be 40 or 30 years?

Mr. EISENBUD. I was going to get to that, Mr. Chairman, and summarize by saying that at the rate information is accumulating we will have the answer long before the hazard develops. We are talking in terms of hazards developing at the present rate in terms of tens of years. We are accumulating significant information from month to month. Whether or not this factor of 3 should be included I think is something that will be known in the next year or so. We will not know everything we would like to know in the next few years, but we will learn enough to eliminate many uncertainties in calculations of the type Dr. Neuman has described.

Senator ANDERSON. Doctor Kulp.

Dr. KULP. I should like to emphasize that I agree completely with Dr. Langham's analysis that the big uncertainty is in the biological hazard where you are going to set the level. This factor of uncertainty of 3 in the distribution should be very firmly fixed within another year at the rate at which data is coming in. This is just a matter of getting an adequate number of samples at the right locations and measurements betwen the bone analysis and the anlaysis of the total fallout that Dr. Eisenbud's group is doing. That will not be important with regard to uncertainty a year hence.

Senator ANDERSON. Dr. Langham or Colonel Hartgering, do you have a comment there?

Colonel HARTGERING. I guess I am the only physician in the group. I don't like to leave the impression that we will know what the somatic relation will be in man. You do not get that in a couple of years. The bone samples and soil samples are coming in rapidly. The type of work I discussed we are doing at Reed. This is obviously continuing, but the somatic effects on man and what this means in terms of injury to him is not going to be available in the next year or two.

Senator ANDERSON. Suppose we should get to another assumption now. Suppose we should say that since other countries are developing weapons that we now raise this rate from 10 megatons of fission products a year to 20 megatons. Would that accelerate pretty rapidly in the time when we might reach these dangerously high levels or what we might assume to be?

Dr. Langham, would you care to comment?

Dr. LANGHAM. I think this borders on something that is more in your field than in ours. What it really amounts to is this: About 10 megatons per year total testing by everybody seems to be just about as much as one would assume we should allow.

Senator ANDERSON. That is a very important and very fine statement. That is one of the things we were trying to get in this hearing, and I am so happy to have it from you, because I know you have spent a great deal of time on it. I am going to try to find out how many people agree with you in a short time. Regardless of agreement, the fact that we bring a figure out on the table and talk about it I think is extremely important because it does indicate your belief, and I think the belief of a great many others that if 10 megatons of fission products is about what we should put in the atmosphere each year, then maybe there is some need to find out what the other people in the world are doing and see if we can hold at that figure.

As you know, I strongly support the idea of constantly improving and testing the devices that we have. I have been very happy at the work at both Los Alamos and Livermore in making these tests possible with as little disturbance to our strontium 90 pictures as possible. Therefore, I am very happy to have this figure from you. You were going to say some more but I did want to break in to say that this is one of the things many people have been hoping to hear from somebody in authority.

Dr. LANGHAM. The implications of this are, of course, that we are no longer the only people testing weapons, which leads automatically to the idea that what one really needs is some type of international agreement with regard to an allocation of fission products that can be injected. Such an arrangement would not place a limit on the total megatons tested but the amount of fission that could be injected into the atmosphere.

This would lead to an encouragement of people to build cleaner weapons or to explode them under conditions which would allow less material to go into the biosphere. The only way one could monitor this would be to get an agreement whereby they would put a tracer on each bomb which would allow anyone in the world to sample their cloud and tell what fraction of the cloud they tested. Then we could monitor how much each country was putting into the biosphere.

The only thing is that in so doing we would gain a lot of information about their bombs which would, of course, mean that it would be hard to get an agreement on such a point.

Senator ANDERSON. Thank you very much. Dr. Eisenbud, we would be glad to have you comment on this upper limit that we have tentatively placed on what we can do. It is a very interesting figure.

Mr. EISENBUD. I think, to use a colloquialism, "We are in the right ball park."

I am also impressed with the fact that the proposed limit is approximately of the same order of magnitude as they assumed the past test-

ing rate. I note that we are talking about reaching the so-called maximum permissible limit, not in terms of months or years but in decades. This suggests that one can feel comfortable that the emergency is not here. We are talking about a hazard that may develop many years from now. We will have ample time to study the problem.

Senator ANDERSON. Dr. Neuman, I would be very happy if you would comment on Dr. Langham's number a moment ago. I hope this is not embarrassing to you.

Dr. NEUMAN. I should say, at the outset, that I am amazed. I felt very lonely up there when I was giving my testimony. Now I find we really are not so different in our predictions after we used our pencils.

Senator ANDERSON. I think that is true generally of scientists when they get together in discussions. That is one of the reasons of having many scientific discussions. That is one of the reasons why the chairman of this committee and the chairman of the subcommittee were anxious to get scientists in here to testify in a fine scientific fashion.

Dr. NEUMAN. It was not very long ago for lack of data that we were swinging rather wildly. The data that have come in recently have sharpened the arena of debate to the point where, as I indicated at the outset, I did not feel we were in trouble, that the present levels are indeed low. This has been stressed many times. It probably needs no further emphasis.

On the other hand, the rates of permissible testing have now narrowed down to somewhere between 2 and 10 megatons per year of fission products released. I think the most important aspect is not whether it is 2, 4, 6, or 10, but the fact that it is a small and finite number, one small enough that we can right now envision an international agreement, as Dr. Langham has indicated, and at the same time, as Merril Eisenbud has indicated, that we can approach this without a scare—or fear—psychology, that there is sufficient time to draw sane and careful agreements embodying necessary precautions so that these agreements can be enthusiastically endorsed. We are really uniquely in a good position knowledgewise to affect an effective ban.

Senator ANDERSON. Thank you. Can 1 of the 5 of you help me on a matter? The statement was made that it might take a hundred years to reach a high level—a hundred years of steady testing—and yet the strontium 90 has a half life of 28 years. How do I try to relate those two things?

Dr. Langham, can you help me?

Dr. LANGHAM. What this means, sir, is that if strontium 90 is decaying with a half time of 28 years, then in about a hundred years we will have shot—or if you want to take Dr. Libby's number, about 50 years—into the biosphere enough strontium 90 so that it is decaying at the same rate we are testing. We will be at equilibrium and we can test for the next 2,000 years supposedly and it would not increase a great deal more.

Senator ANDERSON. I think you explained that to me once before but I wanted to get it in this record.

Dr. Kulp, do you have any comments?

Dr. KULP. I think the only point I would like to add is that in considering this 2 and 10 that we are still shooting at this 100 number. Taking the radical view for just a minute, I wonder if we are fair in multiplying our values times 3, to be very safe, and comparing this

with a hundred when already we have dropped this to a hundred for an average general population. I think the radical might still say we might be allowed 30. The conservative might very well say that 2 would be about 200 times too much. But this will come out next week.

Chairman DURHAM. Doctor, what is that 100 based on? Is that based on medical statistics or what is it based on? Did you just pull the 100 out of the air?

Dr. KULP. I think Dr. Langham should answer that.

Dr. LANGHAM. You were asking about the 100 micromicrocuries and what is it based on?

Chairman DURHAM. Yes.

Dr. LANGHAM. The way it was derived is as follows: We have had a certain amount of experience with radium in people. We think we have a good idea that one-tenth of a microcurie of radium fixed in the bone for essentially one's lifetime will do him no harm. Therefore, we have picked that amount of strontium 90 which would give the worker the same amount of radiation that was given to these people who had a tenth of a microcurie of radium.

So we have said for our occupational tolerance we will take that amount of strontium which is equal to the maximum permissible level of radium. For the world population or for the unoccupied people in this particular pursuit, we will take one-tenth of it. One-tenth of this value which has been selected in comparison with radium is equivalent to the 100 micromicrocuries per gram of calcium in the bone.

So it is based on comparison with radium and our experience in the radium industry. It assumes, sir, that the response to radiation is a threshhold effect. Whether or not radiation is a threshhold effect is not clearly yet established. In fact, the general tendency is to look at long-term changes following radiation damage, including genetics, as being the linear type and not the S-shaped curve I drew on the board. It turns out that 100 micromicrocuries of strontium on the average is about equal to the natural background that we get to the bone.

You can go on from his. As Dr. Lewis has just done in a recent excellent article in Science, you can tie this to the leukemia incidence in the world and you can go ahead and make postulations which will allow you to postulate how many cases of leukemia this may mean distributed throughout the world population. But in order to make that comparison you must assume that you know the effect of radiation or that the increase in radiation damage is linear with increasing dose, and not a threshold response.

Next week is going to be a very interesting session because it is primarily to bring out these very points.

Senator ANDERSON. Very well said, and a fine statement. I thank you for it.

Are there other observations that anyone wants to make?

If not, I would like to ask you if you would sort of document these "chalk talks" as much as you can to us so when we select certain portions for reproduction we may be able to add to it a little bit the bases upon which these decisions were reached, just as you have done here.

May I therefore announce that the hearings will resume on Monday, June 3, and continue through Friday, June 7. June 11 and 12 have

been reserved for testimony from scientific experts who wish to appear but who are not taking part in the first 2 weeks' discussions. The Monday meeting will be in this room.

Just in closing, may I say it has been a real privilege to have such a fine panel for this work today.

Chairman DURHAM. I would like to add my appreciation, too. It certainly has been a fine discussion.

Senator ANDERSON. Thank you very much.

We are adjourned.

(Thereupon, at 4:15 p. m., Wednesday, May 29, 1957, the hearing was recessed, to reconvene at 10 a. m., Monday, June 3, 1957.)

STATEMENT OF DR. H. L. FRIEDELL, SCHOOL OF MEDICINE, WESTERN RESERVE UNIVERSITY[1]

Dr. FRIEDELL. Thank you, sir.

Mr. Chairman, and members of the joint committee, and ladies and gentlemen, I have the unenviable task of trying to introduce an exceedingly difficult and complex subject. We have gathered information on the whole problem of radiation, and the biological effects of radiation, essentially within the past 20 years, and I think it takes a little while before this matures so we can undertstand it fully. Nevertheless, I think there is a place for orientation here for examining some of the basic concepts of what we do know about radiation, about trying to separate various kinds of effects one from the other, when radiation is administered to a biological system. I would like to briefly introduce this.

Time is limited, but I think the others will very readily fill in any hiatuses that exist. There are many none of us can fill in, I think. They will augment wherever necessary the things I talk about.

Representative HOLIFIELD. While we are trying to keep to the schedule, we are not going to cut any witness short. We may ask for documentation, and if you have something that you feel the committee should know, you may proceed to give it.

Dr. FRIEDELL. I think we will want to take a look at how radiation introduces the biological effect, and then we will try to separate some of the things that occur.

It is interesting that radiation we cannot see, hear, feel, or smell, will initiate very profound effects, the way it appears to do this is by this radiation interacting primarily with the atoms that comprise the biological molecules.

The way they interact with the atoms is, in essence, interaction with their electron shells. Most of the physical changes involve these electron orbits, but there are some others which do occur which are essentially insignificant in the broad overall picture.

Specifically, an ionizing particle or powerful photon, a piece of electromagnetic radiation, will come in and pull away an electron out of the atom. Once it has done this, it has now disturbed the atom, made it into an ion, and this ionized atom and the electron will form an ion pair—or it may move the electron into a different energy level. Then it is excited, and may then concern itself with various chemical and biochemical reactions.

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[1] Professional background: University of Minnesota, M. D., 1936; University of Minnesota, Ph. D., 1939; National Cancer Institute Fellow; Chicago Tumor Institute, 1939–40; Memorial Hospital, New York, 1940–41; University of California, 1941–42; instructor in radiology, University of California, 1941–42; United States Army, lieutenant colonel, 1942–46; executive officer and Deputy Chief, Medical Division, Manhattan District. Present work: Professor of radiology, Western Reserve University; director, department of radiology, University Hospitals of Cleveland; director, Atomic Energy Medical Research project, Western Reserve University. Committee appointments: Veterans' Administration, Central Advisory Committee, Radioisotope Section, Reserve and Education Service; National Research Council, Subcommittee on Radiobiology; Atomic Energy Commission, Advisory Committee on Reactor Safeguards; National Bureau of Standards, Subcommittee on Permissible External Dose; State of Ohio, advisory committee on atomic energy. Member; American College of Radiology, American Medical Association, American Radium Society, Association for Advancement of Science, Association of University Radiologists, American Roentgen Ray Society, Radiological Society of North America, Society of Experimental Biology and Medicine, Radiation Research Society, Sigma Xi, Alpha Omega Alpha. (Submitted by witness.)

When this occurs it is obvious immediately that the molecule that is then so vital and important to the cell has been disrupted or disturbed and many things can happen to this molecule.

It is of interest to observe that a cell has roughly 10 to the 14th molecules, and a thousand roentgens, a dose which generally is lethal, will affect only about 10 to the seventh molecules. In other words, one ten-millionth of these are affected, and yet this single injury to an atom or molecule among these many will introduce violent and very serious biological effects. The physical effects are over generally in a very short period of time. Immediately thereafter the disrupted molecules become involved in various kinds of chemical and biochemical changes. And again these are over in a few microseconds. So that the process of the physical effects and the biochemical effects are finished within a very, very short period of time, and yet we observe the biological effect in hours, days, months, and possibly even years later. This is an important concept to retain and keep in mind.

Representative HOLIFIELD. This statement is based on experiments with animals?

Dr. FRIEDELL. These are based on experiments primarily in vitro; in other words, studying tissues or systems outside of complex animal, because it would be very difficult to observe it in an animal itself. From the point of view of the occurrence of biological effects, these are observed in animals—correct.

Representative HOLIFIELD. And is applicable to man?

Dr. FRIEDELL. And is applicable to man.

Representative VAN ZANDT. Dr. Friedell, at this point, do you have information concerning the animals that were exposed to radiation in the Mariannas in the 1954 tests?

Dr. FRIEDELL. I am aware of it. I am not entirely familiar with it.

Representative VAN ZANDT. In other words, the Mariannas tests are not involved in your presentation?

Dr. FRIEDELL. I would say what I am going to present would be involved in all biological effects of radiation. These are the basic things that occur at the beginning. They really are the initial things, and I want to proceed much further in developing this.

Once we get the injury at the chemical and biochemical level, obviously the first unit that may be injured is the cell, and all organisms are comprised of cells, as we know, and are complex organizations of cells. We, therefore, can perhaps begin, once we take a look at this matter, to look at the cells themselves and see what kind of biological effects occur here.

Before I go on to the cell, I would like to make this point: Undoubtedly many of you are familiar with the effects of protecting cells with various chemical and biochemical agents. The way this has been done, in effect, is to take a look at some of the biochemical changes that might occur in a system, and see if it would be possible to prevent them or counteract them. Specifically, we might think briefly of a system that can be affected easily and studied readily, and that is the disruption of the water molecules.

Water is an abundant material in biological systems—ordinary biological systems. This water molecule will undergo exactly the same changes that any vital complex molecule might undergo in the cell itself, because the ionization makes no distinction between these. As-

suming roughly the same conditions, it will ionize water just as well as it will ionize anything else. And if you ionize the water, tear it apart, you now produce radicals, so to speak, which will either reunite or will be modified in some other way.

If oxygen is present, which is another very important element, and present in the biological system, they may combine with oxygen to make very powerful oxidizing agents.

It is presumed at levels we talk about, up to several thousand roentgens, that this effect, which is considered an indirect effect (in other words, producing ionization and modifications of the atoms that may not be directly involved in the biological systems, such as water), in turn produces serious effects, because they become noxious radicals, so to speak. They become oxidants, highly powerful oxidizing agents, and may, in the presence of very vital atoms or molecules, alter them and, in turn, produce these serious biological effects.

Therefore, if you were going to attempt biochemical repair of this, or chemical repair of this, you would either prevent the oxidation from producing radicals, or you might introduce something that is an oxygen acceptor, a reducing agent so to speak, and therefore either spare the effect on the molecules or in some way interfere with this occurring.

One of the common compounds we know fairly well is cysteine, which has sulfhydral groups. We do not need to go into the chemistry and exact nature of these things, but they will accept oxygen, and if you introduce enough of these into the cell, these will, in effect, either combine with the noxious radicals to start with, or by the statistical process of dilution prevent some of the vital cell molecules from being affected.

So that this is one attack that has been made in altering or in preventing this biochemical change from occurring and, therefore, being seriously damaging to the cell.

I said earlier that oxygen needed to be present in order for a large number of these oxidizing radicals to be produced, and this is another way in which we can protect the cell. You can reduce the amount of oxygen. You can either limit the amount of oxygen physically by putting the organisms in oxygen-free atmosphere, or by making some physiological change so that the oxygen is low in vital areas of the cell. When you do this you also protect the organism.

So that our beginning knowledge about the biochemical effects are extremely important in giving us an understanding how biological effects will occur, and how we might modify them in the biological system.

Representative HOLIFIELD. Does that have any practical effect on radiation sickness?

Dr. FRIEDELL. Unfortunately, its practical effect is rather small, for this reason: These things must be done immediately before the radiation is delivered, or at the time the radiation is delivered. Unfortunately, if it is done after the radiation is delivered, this, of course, is no longer effective because all of these things we are talking about would have occurred already.

Representative HOLIFIELD. So this is an interesting scientific fact, but from the standpoint of protecting the people from radiation it is inapplicable?

Dr. FRIEDELL. Essentially and practically inapplicable, but it is important in understanding the mechanisms that occur.

I think it would be well to then begin to take a look at what happens in the cell itself, and the people after me are going to talk about this, and extend some of the basic concepts further. But I believe it would be useful to look at the cells and see what we know about them from a radiological point of view.

We have for a long time studied the various responses of cells to radiation, and have made up a little chart which tells us something about how sensitive these are to radiation, and how easily affected they are by radiation. It is important to understand this because, if you are going to understand what happens to the whole organism, you must obviously know how dependent the whole organism is on the economy of any single cell and how easily this is affected by radiation.

I would like to read this to you from the statement that will be introduced in the record. I will read a list of cells I have made up and listed as extremely sensitive, highly sensitive to moderately sensitive, and insensitive.

The basic cells of the hematopoietic system—lymphocytes, erythroblasts, myeloblasts—closely associated, are extremely sensitive to radiation, and small doses will injure these cells severely.

In the same category, I would include the germinal cells of ovary and the germinal cells of testis. As far as our purposes, I would consider these as highly sensitive, and very readily and quickly affected by radiation.

Mr. RAMEY. When you use the word "lymphocyte" what would be the common name for that?

Dr. FRIEDELL. I would guess that you call these the germinal cells in lymphatic tissues, such as lymph nodes and other tissues that are related to lymph nodes. These also possibly have their origin in the hemotopoietic tissue as well. In other words, the blood-forming organs as well. Perhaps that is what you were referring to.

The next group, which is a little less sensitive—and I would consider these as moderately sensitive to possibly highly sensitive—would be the epithelium of intestinal crypts lining the insides of the intestines, and certain basal layers that originate in the epidermis.

These basal layers of the epidermis and the epithelium of the intestinal crypts, I would say, would be less sensitive, but nevertheless easily affected by radiation.

Now, there are a group of cells which seem to be unaffected except by extremely large doses. I would like to say that all cells can be affected by radiation; if you introduce enough energy, transfer enough energy to the vital systems of the cell, you can destroy them all. But some of the cells require very large doses. Generally the way we look at this is that cells that are highly active and rapidly dividing seem to be affected by radiation more easily than those that are slower growing and more highly differentiated in the sense they are more highly specialized.

These latter seem to be affected by radiation less. I would include in these things like muscles, bone cells proper, liver cells, brain cells, nerve cells, kidney cells. And ordinarily, when lethal doses of radiation are given to the organisms, we will find that these cells are essentially unaffected. You can find no important change in the cells proper.

Now, if you begin to accept this—and it is somewhat difficult to digest without studying it a little bit—you can then begin to understand what happens to organisms as a whole when the organism receives large doses of radiation.

First of all, we can see that certain tissues are going to be promptly injured, and these tissues are going to be the blood-forming cells, such as the leukocytes, and the gastrointestinal cells. Most of the others will be unaffected.

If the organism is vitally dependent on the cells, it will be fatally injured. If it is not vitally dependent upon these cells, there may be modifications, but the organisms proper may not be injured. Therefore, we can begin to understand how we can injure certain cells and yet not affect the organisms seriously.

For example, you can give a fair dose of radiation, which might kill the organisms, to the liver cells alone, and yet the organisms will not die. You can give this kind of radiation to the muscle cells, for example, and the organisms will not die. On the other hand, if you deliver this radiation to the hemotopoietic system, the blood-forming tissue, the organism will die because these blood-forming organs are very vital to the cell.

One of the important things involved is defense against infection. That is, the white cells of the blood-forming organs are very important against infection, and, therefore, reducing the cells would seriously affect the organism and various kinds of infections would rapidly take over.

Representative HOLIFIELD. There is an old saying that a chain is only as strong as its weakest link.

Dr. FRIEDELL. Correct.

Representative HOLIFIELD. When we are talking about the effects of radiation on the human body, and the life span, we must of necessity address our remarks principally to the weakest link in evaluation of the radiation.

Dr. FRIEDELL. Right.

Representative HOLIFIELD. It is of small comfort to know that one section of the body is not so badly affected by radiation, if in the meantime another section of the body which is vital to existence has been destroyed.

I am not saying we should not know this, but I am saying the important thing is to evaluate its effect upon that weakest link in the life cell, the reproductive chain.

Dr. FRIEDELL. This is very true, and when we speak of total body radiation, in other words, when we irradiate the whole organism, then obviously we have to examine the weakest link, and the weakest link would be the hemotopoietic system, and the gastrointestinal tract.

However, when you deal with radio elements, they have certain preferential deposition, so to speak, and therefore, in order to orient yourself, you must understand that certain radio elements that may be administered to an individual will deposit themselves preferentially in one area and, therefore, will essentially have no effect on the gross economy of the individual.

One of the examples I can cite to you is the use of modest doses of radioiodine.

In the adult, the thyroid is a relative insensitive organ, and you can deliver doses to the thyroid in the order of 500 roentgens which

will to all intents and purposes produce no demonstrable effect. On the other hand if you gave 500 roentgens to the total body, or to a very vital structure, you would injury the animal perhaps fatally. This is the reason I introduce this.

Representative HOLIFIELD. By the same token, radio isotopes such as strontium 90, which have been deposited directly into the bone structure and goes right on shooting the powerful rays into the cells around it, would be more damaging than the comparable amount of radiation that was external to the body, would it not?

Dr. FRIEDELL. That is essentially correct. Of course, now we come to one point which is included on our outline—How do we make a decision as to whether certain radio elements are likely to be injurious, and how do we separate radiation coming from radioactive elements or radiation coming from cosmic rays or X-ray machines?

I would like to say this: That all particles or photons (electromagnetic radiation) which are energetic enough to produce ionization will produce the same kind of biological effects, roughly. There are modest differences, but in essence they would produce the same kind of biological effects.

How do we compare radio strontium, for example, with X-rays, or one radio element to another. Let's look at that first.

First of all, the half life of the element is very important. Will it last? Will it radiate a long period of time?—because this is going to determine what the dose is.

Another very important item is how energetic is this particle, and what is the range of this particle. This is tied in with its energy. So we have to know whether it is long lived, what kind of particle it produces, how energetic it is, what is its deposition in the body, will it deposit in vital areas or will it not deposit in vital areas.

These are the kinds of things we have to look at and examine in making any decision about whether a radio element will be serious or not.

Now, strontium 90 happens to fit some of these categories because it is a very long-lived material, and it deposits itself in areas which are vital to the economy of the organism.

Representative HOLIFIELD. Would it be inclined to deposit itself in concentrated areas in the bone, or diffuse through the bone structure?

Dr. FRIEDELL. It appears that strontium 90 is chemically very much like calcium. Therefore, as a good first approximation, we would assume, and I think reasonably conclude, that it distributes itself as calcium does in the bone, which is widely throughout the bone.

Representative HOLIFIELD. But in the case of a broken bone, for instance, that was being repaired, the tendency would be for it to concentrate during the repairing——

Dr. FRIEDELL. During the process of healing, we know there is more calcium deposited at the site of fracture, and, therefore, more strontium 90 would be deposited at the site of fracture.

Representative HOLIFIELD. We hear of bone cancer. Does that take place as a result of bombardment of strontium 90? Does that take place throughout the bone, or is it localized in certain areas of the bone, in the marrow, for instance?

Dr. FRIEDELL. Strontium 90, after you once introduce strontium 90 or, for that matter, almost any element that will seek the bone—and

we have gotten to use the term "bone seeker"—this will distribute itself more or less throughout the bones. Some have special depositions, but it is also the long continued radiation which does the damage. Therefore, it is a question of dose. There is evidence that no matter what radio element you use, if it is a bone seeker, and if it will radiate long enough to give a high enough dose, you will produce bone cancers—at high enough levels. That is what I would like to emphasize.

Senator HICKENLOOPER. Mr. Chairman?

Representative HOLIFIELD. Senator Hickenlooper.

Senator HICKENLOOPER. Doctor, is bone cancer a new thing?

Dr. FRIEDELL. Is it a good thing?

Senator HICKENLOOPER. A new thing.

Dr. FRIEDELL. No, sir.

Senator HICKENLOOPER. Is it something recently discovered?

Dr. FRIEDELL. No, sir.

Senator HICKENLOOPER. Have we not had bone cancer——

Dr. FRIEDELL. Bone cancer has been known almost since time immemorial.

Senator HICKENLOOPER. As long as we have had real medical knowledge?

Dr. FRIEDELL. I think so.

Senator HICKENLOOPER. Bone cancer occurred before we ever had any atomic tests or explosions, did it not?

Dr. FRIEDELL. Yes, it did.

Senator HICKENLOOPER. What would have caused bone cancer many years ago? Is that the absorption of certain nuclear particles, or does it come from some unknown activity of the cells as a starter?

Dr. FRIEDELL. I personally would hesitate to attribute this to the absorption of previous radiation or previous nuclear particles before we began the fallout tests. I think that on the whole this is related to some special biological factor that is yet unknown, and I hope we will hear a little later from one of the other witnesses about some of these special things that might contribute to the production of cancer in general.

Senator HICKENLOOPER. Yes. I mean we have heard a great deal about bone cancer since there has been some radiation released through bomb explosions, but I just wanted to at least assure myself that my belief was right that we had had bone cancer from time immemorial.

Dr. FRIEDELL. Yes, that is true. I will be glad to insert in the record the assertion that bone cancer has been present long before the tests began.

Representative HOLIFIELD. Our concern with strontium 90, though, is that it is an artificial element that is created by thermonuclear explosions and atomic explosions, and it is now a new factor, an additive factor, and experiments have proven that this new element which has been introduced is a cause of bone cancer. That is our concern, is it not?

Dr. FRIEDELL. This is true. But I think there is one very important point we have to look at very hard. That is, what are the levels of radiation? And what evidence do we have that these levels of radiation have produced bone cancer? And what are the bases for

assertions by some that bone cancers will be produced at very low levels in a small percentage of people?

Perhaps later, if I do not forget—I would be glad to be reminded of this—I would offer my humble opinion of this, because I have been looking at this as a radiologist for a number of years, and I am interested in this whole problem.

Representative HOLIFIELD. Why do you not discuss it now? We are on the question now.

Senator BRICKER. May I ask one question before he goes into that?

Representative HOLIFIELD. Yes.

Senator BRICKER. We know that radiation has a tendency to prevent the development of cancer in certain organs?

Dr. FRIEDELL. Yes, sir.

Senator BRICKER. And it is used for that purpose. Would there be any beneficial radiation that might come from strontium 90?

Dr. FRIEDELL. I would say that no radiation is for preventive purposes. I think radiation is used for curative purposes.

Senator BRICKER. For curative, palliative purposes.

Dr. FRIEDELL. Yes, sir.

Senator BRICKER. Would there be any of that effect come from ingested strontium 90?

Dr. FRIEDELL. I could see no benefit that might arise from deposition of radioactive elements.

Senator BRICKER. I have never heard it intimated, but I do know that radiation has been used in the cure of cancer, to help palliate the pain and prevent the growth.

Dr. FRIEDELL. Yes, sir. But in normal tissues I would be opposed, as a matter of fact, to the introduction of radioactive elements as a possible preventive measure.

Senator BRICKER. Of course, we all would. I would not want to take a chance. I wondered if there was any thinking along this line.

Dr. FRIEDELL. No, sir; I do not know of any.

Senator BRICKER. You have not heard it suggested.

Senator HICKENLOOPER. Mr. Chairman, along that line, I would ask one other question, if I may. That is along the line Senator Bricker is discussing.

Could there be any beneficial effect possibly flowing from the introduction of some of these radioactive elements, so far as a cancer that was in the process of formation, or growth within the system which came from other than causes which might have resulted from radiation?

Mr. FRIEDELL. I would say "No."

First of all, the levels of radiation—and again I want to emphasize this: We are talking about entirely different levels. To give you some idea of what the levels are to be curative in the case of cancer (incidentally bone cancer is an extremely resistant form of cancer, and radiation even in large doses is essentially ineffective), the doses that are necessary to cure cancer are in the order of five to ten thousand roentgens. The doses we are talking about, especially from the fallout levels, are in the thousandths of roentgens. So that we are not talking about the same order of magnitude at all.

Senator ANDERSON. I did not follow you on that.

Senator HICKENLOOPER. I think we have done quite a little experimental work in the radioactive iodine in thyroid, and cancer.

Dr. FRIEDELL. Yes, this is true.

Senator HICKENLOOPER. And at least some other attempted specifics along that line.

Dr. FRIEDELL. Yes, sir. In the case of radioiodine, certain cancers of the thyroid are very beneficially affected.

Representative HOLIFIELD. Mr. Van Zandt.

Senator ANDERSON. I want to clear up one thing first.

When you said from five to ten thousand roentgens, then you said the levels we are using here are "thousands" of roentgens?

Dr. FRIEDELL. "Thousandths." Decimal point zero zero one (0.001).

Senator ANDERSON. That is what I wanted. It was not very clear.

Representative HOLIFIELD. Mr. Van Zandt.

Representative VAN ZANDT. Dr. Friedell, in the event of a fracture with the presence of strontium 90, would the strontium 90 in any way slow down the mending of the bone?

Dr. FRIEDELL. I hesitate to answer that, because I have no specific information. But if I may conjecture, I would say it would be slowed down at very high levels of radiation, far above anything we have considered here. And I do not believe you could establish any difference in the growth rate at the kind of levels that are being talked about from fallout.

Representative VAN ZANDT. Then you cannot state whether a low dose of radiation would have any effect on the mending of the bones?

Dr. FRIEDELL. I would hesitate to propose that. I doubt it.

Representative HOLIFIELD. We recognize, Doctor, you are providing us the background statement, and others will go into these different facets.

Dr. FRIEDELL. Very well.

Representative HOLIFIELD. Will you proceed?

Dr. FRIEDELL. With regard to understanding what happens to the whole organism concerning the radiation syndrome, I think we have to look at what happens to the individual from the point of view of the systems that were injured. We try to point out a very cursory relationship between tissue sensitivity, the kind of effects that would produce, cellular effects where the economy of the organs was dependent upon these; and then we can look at some of the systems and pathological findings that might occur.

Since we know the gastrointestinal tract, and the hemotopoietic system are very sensitive to radiation, we can observe, with fairly large doses of radiation, symptoms and pathological effects that are directly related to these. The hematopoietic effect, of course, will appear as a severe drop in the white cells.

I will not go into the kinds of white cells. There are many more competent in this field than I, but this is generally true.

Some of the basic cells in the hematopoietic system are affected, which in turn affects the production of the platelets, which are tissue components in the blood required for the proper function of the clotting mechanism. These are seriously depleted, and under such circumstances you will get all kinds of bleeding tendencies. An individual who is heavily irradiated will show symptoms associated with the gastrointestinal tract, and with the hematopoietic system more or less simultaneously. In the doses that are high, the patient will become nauseated and vomit because of the immediate effects on the gastrointestinal tract, possibly also because some of the vital large

molecules are disrupted, so to speak, by ionization, which we point out can split some of these things up, and it may be these are circulating about and produce some of these effects.

So that an animal that is immediately irradiated in a very few hours may show nausea, vomiting, anorexia, severe diarrhea. This is directly related to what we can observe in the cells themselves, and in the tissue systems. There will be severe hematopoietic changes (the blood changes).

The organism has now lost its defense against infection, and infections will take over very promptly, and we can begin to observe in obvious areas the oropharynx, respiratory, and gastrointestinal tract, ulcerations and infection as a result of this injury to the tissue.

There will be little bleeding points throughout, as a result of interference with platelet formation. If they go on, the animal will be severely injured, and will die, partly as a result of these intercurrent effects, but also because we are unable to replenish some of the vital cells, or the body itself cannot replenish any of the vital cells.

This brings me to a point which we discuss not infrequently——

Representative HOLIFIELD. You are talking of large doses now?

Dr. FRIEDELL. I am talking of large doses in the order of 500 to 1,000 roentgens delivered to the individual.

This brings us to a point of how we might possibly protect the organism against radiation effects.

If we look at some of the very vital cells, it is reasonable to conclude that if it were possible to get these cells to be repopulated, possibly from an outside source, then the animal might be able to recover if the doses have not been really too large.

The recent efforts in this direction have been to get bone marrow cells introduced into the organism that has been heavily irradiated to see whether these cannot repopulate the hematopoietic system, at least until the cells themselves may have had an opportunity to recover.

Representative HOLIFIELD. This would indicate, from a practical standpoint, that you would have to have a bank of bone marrow cells for introduction into the system.

Dr. FRIEDELL. That is correct.

Representative HOLIFIELD. The same as you have to have a blood bank for transfusions?

Dr. FRIEDELL. This introduces many practical problems, and I am not sure it will have any place at all in attacking this problem.

Representative HOLIFIELD. I think it is important to bring this to the point of practical application, because a great many lay readers might think this could be a remedial measure which could be taken in a practical way. Of course, even transfusions would not be of any permanent lasting good if the spleen was affected.

Dr. FRIEDELL. Yes.

Representative HOLIFIELD. Or other blood producing organs.

Dr. FRIEDELL. Right. Essentially, if blood producing organs are seriously affected, it is doubtful if the transfusions have anything other than a transient effect. Generally, in doses of about 500 roentgens, which is presumed to kill, roughly, about half of the humans that may be affected by such a dose, supportive measures might be helpful, such as transfusions, replacing the fluid that is lost as a result of gastrointestinal injury. The use of antibiotics would be very effective be-

cause they would help to combat the infections occurring while the defenses were down.

Representative HOLIFIELD. From a remedial standpoint, this would be more valuable to those who had not received a lethal dose. To people, say, who received 100 or 200 roentgens, these measures would be of some value?

Dr. FRIEDELL. These measures may be valuable even at high doses, because it is possible—if 50 percent survive, say at 500 roentgens, it might be possible to push that up a little further, 60 or 70 percent. This is conjecture. We do not know. This is very important. When we get too high doses, over 1,500 roentgens, it seems that no measures are effective and we are unable to use any of these in any useful way.

Representative HOLIFIELD. Of course, from a practical standpoint, in an exposure of our people, it would be completely beyond the resources of the medical world to give this remedial treatment, would it not?

Dr. FRIEDELL. I think this could be true. But, if we are examining the whole problem, I think we would be overwhelmed by other things that would occur at the same time, and this would be essentially a small problem. There would be many, many more severe and difficult problems.

I have devoted my remarks primarily to the acute effects up to the present time, and we have talked about how we can assess these changes in the whole organism more or less immediately, and in fairly large doses.

It is well also to consider what would happen if the doses are lower, and if the animal survives. Is the animal completely unscathed if radiation has been delivered in smaller doses when comparatively few, or perhaps none have been killed?

Here I think we get into the problems that are very difficult to answer, and very difficult to prove effectively at the present time. This is an area where a great deal of study and research is required.

I would like to divide these, roughly, into three areas:

1. What is the effect on the vitality of the organism?
2. What is the effect on the production of malignant tumors?
3. What is the possible effect on future generations, the genetic effect?

The last I will speak very briefly upon, because many better speakers than I am will discuss it further. But I would like to say something about these points.

First of all, there is evidence indicated in animals with high doses—and by "high doses" I mean accumulation of many hundreds and even thousands of roentgens—that you can produce leukemia in susceptible strains.

I would like to point out that to produce leukemia a susceptible strain of mice must be used—that is, these mice must be such that they are genetically able to produce leukemia spontaneously. If the mice are not a susceptible strain—that is are not leukemia bearing—then the production of leukemia in such a strain is extremely difficult if not impossible. Thus one element that is essential is that the animal must have had inherent tendency to produce leukemia in the first place.

Secondly, tumors have been amply produced in animals with large doses of radiation, and tumors of all kinds. Whether it is strontium

90, phosphorus 32, or total body radiation, or radium, wherever you produce large doses and selective deposition in sensitive areas, you can produce tumors of all sorts. This is unquestioned.

Senator HICKENLOOPER. Benign, or other kinds of tumors?

Dr. FRIEDELL. Let us for the moment consider only the malignant tumors, tumors that will destroy the animal and fit all the criteria that people insist upon being characteristic of malignant, that is, they will spread to other tissues, and generally have the appearance of cancer. I think here is where we get into a problem.

If it is clear that there is evidence that tumors can be produced, and leukemia can be produced in various kinds of organisms under various conditions, it would be well to see if we could quantitate this. In other words, are there twice as many tumors produced when the dose is twice as high?

In general, this appears to be not well controlled, but there appear to be more tumors produced when the doses are higher. Under these circumstances, you can set yourselves up a little model or framework in which you show that the dose is related to the production of tumors, and the number of tumors.

Senator ANDERSON. Can I ask you there what you mean by "when the dose is high"? Can you give us the level again?

Dr. FRIEDELL. Yes. Generally, when we think of high doses, we think of doses in the lethal range, and perhaps I have been a little bit loose in this regard.

If you take animals that have been exposed to a lethal dose, 50 percent dose, that is, a dose in which 50 percent of the animals will succumb, and keep the survivors, the amount of radiation will be very high.

Senator ANDERSON. What I am trying to get to is this: We were talking previously about 5,000 to 10,000 roentgens.

Dr. FRIEDELL. Yes, sir.

Senator ANDERSON. Whereas, from fallout we are talking in thousandths, tiny fractions.

Dr. FRIEDELL. Yes, sir.

Senator ANDERSON. Now the things you are discussing, are they connected with fallout from nuclear weapons in any way, or an accumulation?

Dr. FRIEDELL. It is what we may be discussing, sir, and I would like to amplify this a little bit to show how this concept is approached. I will talk about those very low levels in just a moment.

Senator ANDERSON. All right.

Dr. FRIEDELL. In effect, what I am saying is large doses produce tumors and leukemia, and by "large doses," I am talking about thousands of roentgens, many hundreds of roentgens.

If you set yourself up a model in which you show that these doses will produce tumors and leukemia, and then extrapolate down to low levels, especially on the basis of how the data looked at high levels, you can begin to conjecture that perhaps these lower levels could in a very small percentage of patients or individuals produce these kinds of tumors.

Now, I think what we need to look at, and what this group is going to look at in the next couple of days, is how good are these extrapolations—Is this conjecture? Is this soundly conceived?

I wish I could offer an authoritative statement right now to end all of this discussion, but unfortunately I cannot. However, I would like to say this: That I am concerned about the fact that there are no data at the very low levels. It is just nonexistent. Much below a hundred roentgens, or 25 roentgens in the case of mutations, we have no data.

Representative HOLIFIELD. You are speaking of man?

Dr. FRIEDELL. In animals as well. I am speaking of all complex biological systems.

Representative HOLIFIELD. Have not you been able through following mice, for instance, through several generations, to establish any data of this type?

Dr. FRIEDELL. Yes, but these have been in large doses. These have not been in hundredths, or tenths of roentgens, they have been in doses far larger.

One of the reasons we are using large doses is that you have to have some kind of statistical security in looking at the information. To discover an effect which would occur once in 10,000 times, you would require an inordinate number of biological specimens, and so on.

But I would like to point out that this difficulty exists, and for this reason we do not have really secure data.

Now the people who propose that the doses at very low levels can produce effects have pointed out the data at higher doses are such that permit them to make these extrapolations, and there are many ways of looking at this. You can do it mathematically, you can do it by examing the mechanism by which these effects are produced, and in this way kind of develop some hypotheses which will permit you to make some conclusions.

I feel that the data at the very low levels are based on this kind of hypothesizing, and therefore, correctly are not available at the present time, and perhaps will not be available for a long, long time because of the difficulty.

We should, therefore, be slow in accepting these if we need to use it for a vital decision.

I think at the present time these data are not good enough to make very extreme or vital decisions in this regard. I think all of us should look at this to see what is the truth of the matter and what scientific evidence we can find which will permit us to make these conclusions.

Senator ANDERSON. May I try to translate that to myself and see if I got it correctly?

Dr. FRIEDELL. Yes, sir.

Senator ANDERSON. Do you tell us the data are not now good enough for the Congress, for example, to reach a decision on whether continuation of tests at the present level is wise or unwise?

Dr. FRIEDELL. I would say that, sir. I do not believe the data at the present time are good enough to make conclusive decisions.

Senator ANDERSON. If it is not good enough for the Congress, it is not good enough for the Atomic Energy Commission, either, then, is it?

Dr. FRIEDELL. Let me revise that statement.

Senator ANDERSON. That is the trouble. If it is not good enough for the Congress to reach a decision, it does seem to be good enough for the Atomic Energy Commission to reach a decision. They can sit in their ivory tower and say, "This is all right," but to get back to

the Congress which is having to deal with human beings, the data are not good enough.

Dr. FRIEDELL. I would say the data are not such as to suggest any vital or important decisions which would alter the course being pursued at this time.

First of all, they are not good enough to be conclusive, and there are other reasons I will go into further, which would make me have reservations on what they mean in general.

One of these is, when talking about these doses we are talking about the levels which fit into the dose levels we are receiving right now. If you are interested in numbers, each one of us are receiving or having about 3,000 to 5,000 ionizing events per cubic centimeter per second. Now it is 10,000, now it is 15,000, something of that order. So there are a lot of ionizing events going on now. We are living in a sea of radiation rising from various things, and this will be discussed, I am sure, or has already been discussed.

Senator ANDERSON. I think that is a very useful statement, and I appreciate it. I am only trying to say, if it is difficult for the Congress to get any satisfactory or conclusive answer from the existing data, that it must be equally disturbing, I would think, to the Atomic Energy Commission if they want to take a fair look at it. That is my only point.

Dr. FRIEDELL. I would think—if I were going to conjecture again, on how they are looking at it. I think they are disturbed by this, and I think their examination of the data would suggest to them there is no reason to stop these tests because of the levels of radiation. The levels are apparently at levels which are far below levels which we have established as being the acceptable doses, and are quite within the range of radiation occurring at the present time all around.

Senator BRICKER. Mr. Chairman?

Representative HOLIFIELD. Senator Bricker.

Senator BRICKER. Is there any thinking along the line that, if there were no background ionizing radiation at all, the human body would be devoid of cancer?

Dr. FRIEDELL. I do not have any opinion about this, sir. But again I will conjecture that I think the cause for malignant disease lies in some biological derangement that is really not related——

Senator BRICKER. To radiation?

Dr. FRIEDELL. Alone.

Senator BRICKER. But ionization of the cells?

Dr. FRIEDELL. Right.

Representative HOLIFIELD. You used the word "alone"; it is not related alone to that point. You think there may be other causes? I was afraid that word was missed by the audience. I think it is important.

Dr. FRIEDELL. I think at the proper levels, high enough levels, these effects can be produced. At the very low levels where the levels begin to approach the natural levels we are facing, I think there is grave uncertainty. This, of course, is concerned with the whole concept of whether the effects will be occurring at low levels in the same rate that they are occurring at high levels, and whether there is such a thing as threshhold. In other words, is there some level below which nothing will happen?

Again, this is very difficult to establish. The evidence, as I see it, is inconclusive in this direction, and if I had to choose, if I had to make a decision now, if I were compelled to make a decision, I would hesitate to accept this concept that a threshhold does not exist.

Senator BRICKER. That is the reason I asked the question, frankly. It is your thinking, then, that there is a biological cause of these abnormal growths in the human body?

Dr. FRIEDELL. I do, sir.

Senator BRICKER. Above and beyond and separate from the radiation?

Dr. FRIEDELL. Yes; I do.

Representative HOLIFIELD. Will you state your observation in an affirmative way rather than a negative way? And then tell me if you apply that equally to somatic as well as reproductive cells.

Dr. FRIEDELL. I sort of left out the reproductive aspect of this.

Representative HOLIFIELD. That is just what I thought maybe you left out. That is why I wanted you to restate it.

Dr. FRIEDELL. I would say, from the point of view of production of tumors, and leukemias, I would hesitate to accept the concept that a threshold does not exist. From a point of view of genetics—now I am in a field where I am even less familiar—I think the data are not unassailable, but I think they are stronger than they are in the concept of cancers or leukemias.

Again I would like to point out the data on mutations and genetic effects do not exist below 25 roentgens.

The basis for making these decisions is careful study of the data, by protracting the radiation, by fractionating it, by observing the effect of dose, and this gives them a line which can be extrapolated down below. I have no objection to these extrapolations, and ever since Descartes introduced the coordinate system, this is a privilege of all. I do not really understand whether these things necessarily follow this rule. I would think I would want a much better and much more carefully controlled examination of the effect at very low levels.

Representative VAN ZANDT. Mr. Chairman?

Representative HOLIFIELD. Mr. Van Zandt.

Representative VAN ZANDT. Dr. Friedell, to be conclusive, would you go into a little more detail as to what must be required?

Dr. FRIEDELL. What must be required?

Representative VAN ZANDT. Yes.

Dr. FRIEDELL. As far as our studies go?

Representative VAN ZANDT. Yes.

Dr. FRIEDELL. I think probably the most important thing is to look at the basic aspects of what occurs in biological systems, so that we can understand the mechanism, so that we can see whether once we understand this mechanism it fits in with the data which we already have. And here I feel is where the greatest possibility for really learning something about it exists. I would like to see this emphasized over and above the efforts to perhaps use 10 million mice at very low levels. I would think that basic studies of biochemical effects, the possible way in which these things occur, would contribute more than doing such statistical studies——

Representative VAN ZANDT. Would you apply a time factor?

Dr. FRIEDELL. I would hesitate to apply a time factor, but since I am making all sorts of conjectures, I will add one here.

I will say that perhaps in 5 to 10 years we would have a much better understanding of this.

Representative HOLIFIELD. Of course, if your understanding at that time had to be revised downward as the chart this morning has been revised downward, we would be dealing then with an accumulation of substance which would be ineradicable, and we would have it; would we not?

Dr. FRIEDELL. Yes.

On the last page of my little statement, I tried to put these things together. I think two problems exist.

First of all, I think there is a problem of examining the data scientifically to know where the truth lies.

Assuming the correct consequences of this, assuming no threshold, and all radiation is injurious and produces some effect, I think we have to fairly assess this kind of hazard compared with the hazard which now exists. I do not feel we have yet really looked at this in an unbiased and nonemotional manner. I think it can be done, especially if we look at it over a long period of time so we do not rush into any important decisions at this time.

Senator BRICKER. You have discussed the control of abnormal growths, the cause of them, the somatic effects in a limited way. What have you to say about the length of life?

Dr. FRIEDELL. Here again I do not have any good, well-founded opinion. The data that are available indicate that for large doses in animals, there is a decreasing survival due to all the causes that would occur ordinarily in these animals. In other words, they die of various things, only these various causes of death appear a little earlier in heavily irradiated animals.

Again the same problem exists. Can you extrapolate down below?

This figure we heard earlier that somebody will have suffered a loss of 20 days in survival. It seems to me there can be no data at this level, because this would require an inordinate amount of animals at very low levels to establish this, and I just do not have that kind of sureness about studies in which you observe one event in hundreds of thousands of others.

From the point of view of the span of life, I feel for projections to low levels this falls in exactly the same kind of category. We cannot determine what is happening at very low levels.

I think I can understand the reasons and conjectures and hypotheses of people who propose that this occurs, but they make me uneasy, and I am loath and not ready to fully accept them. I think they are not incontrovertible.

From the point of data on humans, there is some published evidence to show a radiologist may, by the nature of his activities, have received more radiation than others. I am a radiologist myself. I turned some data recently published over to the statistician, and he wrote me a letter saying that these data were suggestive, but by no means conclusive. And the way in which you sample the various groups makes a tremendous amount of difference, and even though averages of the compared group, for example, might be the same, the distribu-

tion could make a tremendous difference. I know this has been touched upon by others who feel the same way.

Representative HOLIFIELD. We found that averages are a little bit unreliable to rely on in some instances.

Dr. FRIEDELL. Yes.

Representative HOLIFIELD. Thank you very much. Are you planning to stay the rest of the day? We might have you on in the discussion late this afternoon.

Dr. FRIEDELL. Yes, sir.

Representative HOLIFIELD. Thank you, sir. Your prepared statement will be placed in the record at this point.

(The prepared statement referred to follows:)

MATERIAL PRESENTED BEFORE THE JOINT COMMITTEE ON ATOMIC ENERGY BY H. L. FRIEDELL, M. D.

The biological effects that are observed when tissues are irradiated must begin as a result of the physical interaction of ionizing radiation and the atoms that comprise the biological specimen.

This interaction appears primarily as ionization—that is, ejection of an electron from the orbit by excitation, in which the energy level of the electron without ejection probably also plays a part.

The excited and ionized atoms and molecules then appear to interact in various ways, eventually producing profound chemical and biochemical change. The immediate physical and chemical changes are probably over in fractions of a microsecond, or at most a few microseconds. The biological effects may not appear for hours, days, or months.

One interesting aspect of this energy absorption is that only a small absorption of energy produces such widespread biological effects. One thousand roentgens, a lethal dose, involves only a very small fraction of a calory per gram (2×10^{-3} calories per gram). Another way to look at this is that the energy which is absorbed appears to affect directly only about 10^7 molecules in a cell which generally contains 10^{14} molecules.

In outline form, we need to think of the chain of events as (1) physical interaction, (2) chemical and biochemical changes, (3) cellular changes, (4) going on to tissue and organ system alteration, and, finally (5) injury to the whole organism.

The chemical and biochemical effects which occur are at the present time somewhat obscure and receiving much study. One of these effects that has been of interest and which appears to be tied up with some of the observable biological changes are the indirect effects resulting from the disruption of the water molecule abundantly present in living tissue. In the presence of oxygen, this results in producing highly active water radicals which in turn attack vital molecules in the cell since they are very active oxidants.

It has been found that, by depriving the cell of oxygen during the radiation period, these effects can be markedly minimized. By introducing chemicals which are in themselves oxygen acceptors, the oxidation effect on sensitive tissue systems may be spared and the radiation injury is markedly minimized.

At the present time, the best working concept is that the indirect effects are very important at the levels of radiation with which we are concerned (500 to 1,000 r.), that efforts to correct or prevent the chemical and biochemical disturbances as a result of disruption of the water molecules protects biological systems in an effective manner. It should be pointed out that this must be done during the radiation and is completely ineffective after the radiation has been delivered.

The cellular effects have been quite thoroughly studied. On the whole, the nucleus is known to be more sensitive than the cytoplasm. Cells appear to be affected primarily with respect to their function of division and recent studies have, therefore, been directed at this aspect. From the biochemical point of view, the nucleic acid metabolism, and particularly DNA in the nucleus, has received considerable attention.

From a general point of view, it is best to look at the cellular changes and try to understand the difference between cells and their place in the economy

of the whole organism. At one end we have extremely sensitive cells. These may be listed as follows:

(*a*) Extremely sensitive: Lymphocytes, erythroblasts, germinal epithelium of testis, myeloblasts, germinal cells of ovary.

(*b*) Highly sensitive to moderately sensitive: Epithelium of intestinal crypts, basal layers of the skin.

(*c*) Insensitive: Connective tissue, bone, liver, pancreas, kidney, nerve, brain, muscle.

An estimate of the variation in sensitivity permits us to understand better the effects on tissue and on the whole organism. The effect on the whole organism is obviously determined by how dependent the organism is upon extremely radiosensitive tissues. Since the hematopoietic system is one of the extremely important tissues upon which the organism vitally depends, it can be explained that irradiated animals can be readily injured by comparatively modest doses. The animals suffer infections and will die a hematopoietic death if some measure for correction is not instituted. The epithelium of the gastrointestinal tract is less sensitive but nevertheless readily affected by large doses of radiation. At the lower dose levels there is rapid recovery. At the higher dose levels recovery is markedly impaired and the animal may succumb to what is known as a gastrointestinal death, sometimes even before the hematopoietic changes can manifest themselves.

Many tissues are quite unaffected by radiation at levels which would cause death of the whole organism. Therefore, under certain circumstances, particularly when certain radio elements are used, considerable radiation may be delivered without seriously affecting the organism as a whole since the radiation is confined to a comparatively insensitive structure. Also, radiation delivered to sensitive tissues which may not be vital to the organism proper will have comparatively little effect on the individual. As an example, radiation delivered to the thyroid, which in older individuals is comparatively insensitive to radiation, will not produce any appreciable effect on the whole organism. Also, radiation delivered in modest doses to the gonads may produce sterility but will otherwise appear to have no demonstrable effect on the individual proper.

It would be well to point out that the manner in which radiation is delivered is highly important in considering the possible biological effects (excepting genetic changes which will be discussed briefly later). Protraction and fractionation of the radiation markedly reduces the total somatic biological effect. Radiation delivered to specific parts of the body markedly alters the response so that shielding of part of the body increases the dose necessary for lethal effects.

Generally, radiation delivered over a long period of time gives some of the tissues an opportunity to recover (a process which is poorly understood) and, therefore, increases survival.

Specifically, it is well to point out that species sensitivity varies among mammals. Following is a list which gives some concept of the range that may exist:

LD_{50} dose:	*Roentgens*	LD_{50} dose:	*Roentgens*
Guinea pigs	200	Rats	700
Pigs	300	Hamsters	750
Dogs	350	Rabbits	800
Mice	450	Bacteria	100,000
Monkeys	500	Viruses	1,000,000

Man is estimated to fall somewhere halfway through this range of mammals and the LD_{50} dose (that is, the dose necessary to kill 50 percent of the individuals) is presumed to be about 500 roentgens.

As a result of whole-body radiation, certain specific tissues effects are produced. These in turn determine the clinical syndrome. Briefly, the effects which first appear are nausea and vomiting, which can be explained on the injury to the gastrointestinal tract. Prostration, diarrhea, and anorexia may promptly occur with larger doses—again the result of interference with gastroitestinal function and dehydration. The blood forming tissues are simultaneously affected, but evidence of their severe depression is slightly delayed. There is marked depletion of the white cells—later the red cells. The elements involved in clotting are seriously affected and hemorrhages as a result of this derangement soon appear. The individual is susceptible to infection for two reasons—one, depletion of the white cells, and secondly, by impairment of the ability to form antibodies. As a result of this susceptibility to infection, the

oropharynx, respiratory and gastrointestinal tract are prone to ulceration and infection. The central nervous system is essentially not affected.

The neuromuscular system and the specific function of the liver and kidney appear not affected at lethal doses, fitting in with our general concept of radiation sensitivity of tissues. Epilation occurs as the dose approaches the LD_{50} range, since the basal cells of the skin and their derivatives are quite sensitive.

Of concern also are effects which do not appear immediately as the result of radiation but are either postponed until late in the life cycle of the organism or may be observed only by special methods of testing. One of these is the question of general impairment of viability of the organism which may be susceptible of determination by observation on longevity.

In animals at fairly large doses there is good evidence that animals do not survive as long as nonirradiated controls. Whether this may be extrapolated to low dose levels is uncertain and is by no means conclusively established. There are no good data at levels of less than 100 roentgens and those that are available do not indicate any change in longevity. Recently, there has been presented evidence that radiologists who, having received more radiation than others by the nature of their activities, have suffered a reduction in their life span. Although the data are suggestive, statisticians have seriously questioned the significance of these data because of the method of sampling and of the uncertain relationship of the age groups.

Another late consequence of radiation in which the animal survives is the production of malignant new growths (tumors of various kinds) and leukemia. In animals, large doses unquestionably produce an increase in the incidence of cancers and leukemias. It should be pointed out that it is necessary to use a susceptible strain and that in certain insensitive strains it is not possible to produce these changes. The question as to whether this occurs in man, I think, has been amply demonstrated.

I believe there is evidence to show that when humans are heavily irradiated, tumors and lukemia will appear. The question is whether this occurrence may be satisfactorily quantitated and attributed to low levels of radiation. We have no data in this respect. Theoretically, considerations suggest that this may occur, but at present are entirely in the realm of hypothesis and must be considered inconclusive.

A third important late effect is concerned with the injury to the genetic tissue of the organism, and here I believe we should now make a distinction between sterility and genetic alteration.

The cells of the gonads which develop into sperm and ova and concerned with reproduction are extremely sensitive—comparable to that of hematopoietic tissue, and are injured with modest doses of radiation. From the point of view of sterility, it requires about 300 to 400 *r* to induce sterility in the female and perhaps 500 *r* to induce sterility in the male—that is, there is essentially complete loss of viability of the reproductive cells so that no progeny is possible.

This must also be distinguished from injury to the cells in the reproductive organs having to do with sexual characteristics—that is, male and female characteristics and other hormonal influences. These cells are not readily injured by radiation and are comparatively insensitive. Although it is easy to produce sterility, it is very difficult to eliminate the normal sexual characteristics—that is, male and female characteristics and other related functions.

The important change which has significance for all of society concerns itself with the alteration of the genes proper. Without going into the concepts of physical characteristics of the gene and its position in the reproductive apparatus, it is sufficient to say that these alterations are known as mutations which are essentially uninvolved in the reproductive capacity of the individual but produce its effects in subsequent generations.

Briefly, these mutations as a result of radiation appear to be similar to mutations produced by other causes. (Radiation is not the only cause for mutation.) The number of mutants appears to be directly related to the amount of radiation; that is, doubling the dose doubles the number of mutants. It is presumed that the radiation would have exactly the same importance and effect no matter how low the radiation level. It should be pointed out that we have no data below 25 roentgens and that extrapolations to very low levels are made on theoretical grounds.

It has also been generally accepted that the radiation effects on the extent of mutations are cumulative. That is, whether the dose is given at one time or distributed over long periods of time, the effects are exactly the same. Although

these data appear sound, they may still be considered incomplete and there are minor discrepancies which have appeared and which may require some elaboration. There is also reason to discuss the place of the production of mutations compared with the general mutations that are being retained in the genetic pool.

The radiation dose necessary to double the mutation rate appears to be about 50 roentgens. It should be clearly understood that this is an estimate, and competent geneticists have submitted proposals from 5 to 150 roentgens.

It is known that there are many diseases of heredity (that is, genetic origin) which are almost certainly the result of mutants and may therefore be examined in the same light as mutants due to radiation. Since these may be retained in the pool because of the amelioration of the rigors of selection, it would be possible to assess all of these mutants in terms of roentgens. Therefore, a better estimate of the total hazard as a result of low doses of radiation would be possible.

It appears that most mutations appear to be of the recessive variety which would therefore, in effect, not permit their immediate recognition or elimination until after many, many generations. This means that the mutant will become widely disseminated in the genetic pool. It also means that the radiation received by a small segment of society may be of little consequence since the radiation to the total population would be roughly the ratio of the total population to this small segment. The genetic effects are best surveyed from the point of view of its effect on the whole population and, generally speaking, the genetic effects become significant when delivered to either the whole population or large segments of it.

I am inclined to make these observations from the point of view of long-term effects of radiation—that is, the production of tumors, leukemia, and the decrease in longevity.

All data presented at the present time are either presumptive or speculative for very low doses. They rest in hypotheses derived from the theoretical aspect of dose effects at high levels. I believe there is sufficient uncertainty so that it would be unwise, and in fact nonscientific, to make conclusive decisions on the basis of these extrapolations.

With respect to the genetic effects, which have been extensively studied by biologists, there are sufficient uncertainties even in these data so that it is not possible to accept them as entirely unassailable. These include the fact that data at low levels do not exist, that data are confined at present to Drosophila and to a few small mammals such as mice, that the mutation rate due to ultraviolet radiation appears to be nonlinear, and there is reason to believe that some of the energy transfer with ionizing radiation is in part of the same character as that with ultraviolet radiation. Man has existed since time immemorial in a sea of radiation where fairly large differences because of altitude and special geographic places also are present. It is difficult to reconcile some of the conjectures to be made at very low levels with the natural radiation doses to which man has already been subjected.

To my mind, the problems of biologic effects at low doses are in essence these:

1. The data on the biological effects at low levels of radiation are by no means conclusive. At best they must be considered highly presumptive This suggests that extensive, carefully considered research is necessary.

2. Even if one assumes that the low-level effects of radiation are established, the problem of establishing the hazard and the risk rate at these levels has not yet been fully and properly evaluated. With specific regard to the fallout problem, it is my opinion that at the low levels which now appear to exist, no immediate decision on any vital problems is now necessary.

With respect to the general overall consideration regarding all-out nuclear warfare, a different order of magnitude is introduced and I must join with others in pointing out that this is fraught with the direst consequences, and that every effort must be expended to the elimination of nuclear warfare.

With specific respect to the fallout problem, it is my opinion that with the low levels which now exist, no precipitate alteration in our course is required. There are a number of organizations on radiation protection that are continually looking at this problem with representatives of all disciplines, and they are gradually modifying the acceptable levels wherever it is found desirable.

Representative HOLIFIELD. Before we hear our next witness, I would like to insert in the record a report from the Armed Forces Institute of Pathology.

(The report referred to follows:)

ARMED FORCES INSTITUTE OF PATHOLOGY,
WALTER REED ARMY MEDICAL CENTER,
Washington, D. C., May 16, 1957.

Subject: Statements for congressional hearings.
To: Chief of Research and Development, Department of the Army, Washington, D. C.
(Attn. Chief, Atomic Division.)

The following report is submitted in accordance with a verbal request to the Director of the Armed Forces Institute of Pathology from Lieutenant Colonel Ransom of the Research and Development Office of the Department of the Army, May 14, 1957. The time limit of 24 hours for the preparation of such an extensive report, and the absence on TDY of the Chief and Assistant Chief of the Section on Radiobiology, Armed Forces Institute of Pathology at the Nevada test site on Operation Plumbob 4.1 necessarily resulted in some limitation on presentation of material requested which under more favorable circumstances could possibly be more fully covered. The discussions and answers as presented represent a combined effort of the professional staff of the Armed Forces Institute of Pathology with some assistance obtained from Naval Medical Research Institute and Walter Reed Army Institute of Research.

W. M. SILLIPHANT,
Captain, MC, USN, The Director.

CONCERNING TOPIC IX

A detailed discussion of the occurrence of strontium 90 and cesium 137 in the atmosphere and its uptake and behavior in man is contained in the remarks prepared by Dr. Willard F. Libby, Commissioner, United States Atomic Energy Commission, for delivery before the spring meeting of the American Physical Society, Washington, D. C., April 26, 1957. A copy is attached (see p. 1519). These findings have also been discussed and confirmed by Drs. J. L. Kulp, W. R. Eckelmann, A. R. Schulert (Strontium 90 in Man. Science, 125, p. 219, February 8, 1957). However, Dr. Lapp (Science, vol. 125, p. 933, May 10, 1957) criticizes some of these conclusions, and points out some pertinent factors for consideration. His critique is attached (see pp. 694, 704).

CONCERNING TOPIC X

SOMATIC EFFECTS—PATHOLOGY

A. Distinction must be made between the somatic and genetic effects of radiation

The genetic cells carry on from generation to generation the damage which has been received. The somatic cells receive the injury but this is not transmitted from one generation to another. The effects of high level radiation may be manifested not only immediately but also after a delayed period. There are also effects from a low level of radiation and some organs are more readily injured than others.

B. Early effects of exposure of animals and man to external radiation

1. *Gama and X-radiation.*—Syndrome of radiation sickness. Individuals receiving doses of total body radiation can probably be best divided from a standpoint of prognosis according to the clinical signs and symptoms they present. This is particularly true because of individual variation in the response of different people to the same dose of irradiation. Roughly, casualties may be grouped into those in which survival is improbable, possible, and probable.. There is, however, no very sharp line of demarcation among the groups. The signs and symptoms have been described for the Japanese casualties at Hiroshima and Nagasaki in a report by Liebow, Warren, and DeCoursey in the American Journal of Pathology and in a report entitled "Some Effects of Iionizing Radiation on Human Beings" involving particularly the Marshallese casualties. In doses of more than 3,000 roentgens one may encounter a hyperacute reaction within an hour whereas in the range of about 3,000 to 2,000 roentgens nauseau, vomiting, and some diarrhea and fatigue may be the initial reaction in 2 to 4 hours after exposure. In individuals receiving doses between the range of 2,000 down to 800 roentgens there may be a period of relative well-being following the initial reaction for a few days and then a gradual return of

anorexia, malaise, severe diarrhea, thirst, fever, delirium, and leucopenia. In individuals between 800 and 300 roentgens this reaction may come in about 2 to 3 weeks with acute bone marrow failure, ulceration of the gastrointestinal tract, epilation, and bacterial infection. A subacute reaction consisting of subacute marrow failure, subacute infection in the lungs, brain, and bowel and general malnutrition may manifest itself in about 6 weeks after exposure in patients receiving 350 to 250 roentgens. In those receiving less than 250 roentgens and in some survivors from doses in the lethal range, there may be a chronic reaction of varying degrees extending for a period of months or longer of malnutrition, chronic anemia, premature aging, leukemia, and possibly neoplasia. The above acute syndrome varies with the geometry of the source of radiation in relation to the exposed person.

(*a*) Marshallese: See reference.

(*b*) The Los Alamos incidents referred to under X, B, 1, b are covered in a single entire issue of the Annals of Internal Medicine February 2, 1952.

2. *Beta radiation—Beta burns.*—As long as only very penetrating radiations are involved in exposure of the entire body, skin injury would rarely be a problem, because a dose sufficient to permanently affect it would kill the patient before dermatologic lesions were of any concern. Epilation is an exception to this statement since it was present, though only temporarily, in some of the Japanese atom-bomb victims. During fallout from bomb clouds, however, radioactive particles may settle on the exposed skin of anyone outdoors, and the hazards of beta particle radiation burns are added to the effect produced by penetrating gamma rays. Beta particle burns resulting from fallout first came into public prominence with the announcement that some of the inhabitants of the Marshall Islands were exposed to such a hazard during the 1954 weapons-testing program. However, the problem of fallout was not a new thing to those charged with the responsibility of conducting tests of nuclear weapons. At the time of the first nuclear detonation at Alamagordo, N. Mex., a number of cattle about 10 miles from the blast received fallout on their backs. The fine particles were retained by the hair, and in a few weeks epilation and blisterlike lesions occurred. The lesions healed much like ordinary thermal burns, and the hair grew again, but the original red color was replaced by grey or white. Late effects of this exposure have recently been reported in studies conducted at the AFIP.

(*a*) Marshallese: In the Marshallese group individuals were exposed to gamma and beta radiation. The injuries due to beta burns were local and confined to the areas of contact. The reaction manifested itself by initial tingling and itching at the time of exposure, followed by erythema and edema in a few hours, lasting for 2 to 3 days. There was then a latent asymptomatic 3- to 5-day period with a return of secondary erythema with vesicle formation. Drying and desquamation takes place in about 3 weeks and the individual then may enter a chronic phase with some atrophy of the involved parts taking place. Where both types of radiation occur concomitantly, the gamma radiation generally overrides the beta in clinical significance.

The effects of ionizing radiation amongst the Marshallese has been extensively covered in the report Some Effects of Ionizing Radiation on Human Beings from the Naval Medical Research Institute, Bethesda, Md.; United States Naval Radiological Defense Laboratory, California; and Medical Department, Brookhaven National Laboratory, Upton, N. Y.; United States Atomic Energy Commission, July 1955. Values for gamma and beta radiation could only be approximated but there was a high enough dose on the skin to produce lesions. The estimated "point source" doses were:

Rongelap, group I, 260 r.
Uterik, group IV, 20 r.

Some of the patients showed acute symptoms of diarrhea and vomiting and itching and burning of the skin in group I (Rongelap) but none in group IV (Uterik) showed these symptoms. Biopsies were taken of the skin at various stages. These showed changes typical of radiation reaction. Ultimately there was complete restoration of the skin.

(*b*) Other examples: Skin lesions, acute, chronic and neoplastic were one of the earliest hazards to be recognized in human beings exposed to low energy radiation. Human casualties from ionizing radiation have been of increasing concern since the turn of the century. These include in addition to skin lesions, a higher incidence of leukemia among radiologists than among the general population. The occurrence of cataracts among early workers with cyclotrons, the

high incidence of cancer of the lungs as an occupational hazard among certain miners in Czechoslovakia, and the bone cancers that occurred in watch dial painters in this country.

(c) *The early effects of internal radiation are dependent upon the amount, type, and area where material is deposited*

If the material is insoluble and taken into the gastrointestinal tract, it might produce only local irritation of the intestinal tract but not be absorbed within the body economy. Another example would be in giving I–131, the early manifestations of which would be some soreness of the thyroid and hematopoietic changes (approximately 2 to 3 weeks). However, this would require a large therapeutic dose.

(d) *Criteria include*

Half life (the physical and biological half lives), body utilization, solubility and excretion.

(e) *The degree to which late effects, readily produced in animals by single "massive" doses of total body ionizing radiation, may turn up in survivors in Japan is still under investigation*

Such effects include the occurrence of tumors in various organs after long latent periods following a single exposure to total body radiations in the lethal dose range; genetic mutations that affect subsequent generations; and aging. Such injuries are obviously far more difficult to follow in man than in controlled laboratory animal populations. It is only very recently that quantitative data on genetic mutations have been extended from fruitflies to a mammal, namely, the laboratory mouse, and this may still be a long way from the problem in man. An increased incidence of myelogenous leukemia and radiation cataracts has been found in the followup studies of the Japanese to date.

In the course of radiotherapy, it seems that serious late effects can result from a single exposure or a series of exposures to X or isotopic radiations. Thyroid cancer has resulted in children being given X-radiation for thymic disease. Leukemia has also been reported in individuals receiving X-radiation for spondylitis or those receiving repeated I–131 for cancer. The increased incidence in leukemia in the Japanese exposed to nuclear explosions at Hiroshima and Nagasaki is the only example of this disease occurring in man after a single acute exposure of the entire body to ionizing radiation.

(f) *General*

Exposure of the entire body, or a major portion thereof, to significant amounts of penetrating ionizing radiation interferes with the proliferation of normally self-replenishing tissues essential to life, namely the bone marrow, and under certain circumstances, the small bowel epitheliu. Within the lethal dose range, most of the stem cells responsible for the continued replacement of these tissues are still capable of recovery, with survival being dependent upon the time and extent of regeneration. The acute radiation syndrome, therefore, is a clinical entity resulting from an action of ionizing radiation from which recovery is potentially possible. It is a diagnosis that includes the signs and symptoms that evolve following exposure of the whole body or a major portion thereof to penetrating ionizing radiation.

It has been estimated that the human bone marrow pours into the blood stream each day 1 trillion red blood cells, 10 billion granulocytes and 500 billion platelets. The epithelial lining of the small bowel of a rat is replaced every day and a half. In the human, the rate of replacement is not accurately known, but it is also quite rapid. The rate of cell division in these tissues, throughout life, is as high as that encountered in a great many malignant tumors. Interference with the continuous proliferation or replacement of these tissues results in a secondary aplastic anemia and damage to the integrity of the alimentary tract.

The sequelae of panhematocytopenia from any cause have been known for a number of years. They include (1) thrombocytopenic purpura, (2) anemia, and (3) agranolocytic infections.

Anemia is due to a variety of factors including (1) inadequate hematopoiesis, (2) widespread purpuric hemorrhage, and (3) increased destruction of red blood cells. Hemorrhage is most prone to occur at sites of injury due to radiation damage, accidental trauma, and physiologic activity. Huge numbers of extravasated erythrocytes return to the bloow stream via the lymphatic system and thoracic ducts. Many are phagocytized by macrophages. Increased destruc-

tion of red blood cells occurs, and leads to increased deposits of hemosiderin in the spleen.

Vincent's Angina is a common complication of agranulocytosis from any cause. Mechanical trauma and poor oral hygience invite septic ulcerations, particularly in the presence of agranulocytosis. The tonsils, as is well known, may serve as portals of entry for bacteria with the subsequent development of a bacteremia or septicemia.

Focal hemorrhages from radiation-induced thrombocytopenic purpura may be followed by septic ulcerations of the large bowel and the onset of diarrhea several weeks after exposure, even though the dose of radiation to the abdomen has not been sufficient to permanently interfere with recovery of the more radiosensitive small bowel. Such things as focal hemorrhages, delayed vascular reactions to irradiation, and to injured tissue, damage to the solitary lymphoid follicles and smoldering superficial infections contribute to the development of such ulcers.

Recovery of the small bowel epithelium generally occurs following exposure to total body ionizing radiation up to 100 percent lethal dose. Failure of recovery, however, may be an important factor in early deaths resulting from exposure to supralethal doses, or where the small intenstine is the principal site of injury.

1. In the various mechanisms of response of man to radiation the injury is caused by the energy imparted by the various ionizing radiations. This energy is dissipated in matter through excitation or ionization, depending upon the energy level of the radiation. The total ionizing action is related to the number of ion pairs formed per unit limit. This may be expressed as the density of ionization. Alpha particles have a high ionization density but a short range; beta particles a less dense ionization pattern but a range of a few millimeters in tissue and a few centimeters in air. Gamma radiation has a long range with the lightest ionization density. Neutrons have a somewhat shorter range than gamma rays. This is significant in that gamma and neutrons can penetrate with ease into the body from external sources. In contradistinction, alpha and beta particles are limited in such penetration from practically 0 for the alphas to a few millimeters through the skin for the betas. However, from an internal source, alpha emitters take on particular importance because of their unrestricted local activity over very long periods of time.

Certain effects of ionizing radiation on living cells in both plant and animal tissues have been clearly established for many years. These include (1) acute cell destruction, associated with nuclear vacuolization, rupture, and fragmentation; (2) a variety of chromosomal alterations and; (3) delay in division. Less well understood actions include (1) differentiations, aging and death of so-called vegetative intermitotic or stem cells; (2) effects which interfere with the action of humoral factors involved in the regeneration of certain tissues, including derivatives of the reticuloendothelial system; and (3) effects involving the cellular and noncellular immune responses of the organism.

2. Significance of different types of ionizing radiation in process: There are several important differences between lesions to be expected from penetrating radiation and from beta radiation from fallout particles. Once the beta particles have reached the surface of the earth, they contribute to the general activity of the area, but do not endanger the skin surfaces to any extent, because they penetrate only a few millimeters of tissue and almost any covering affords some protection. Overexposure to gamma rays may be followed by the acute radiation syndrome, and death or recovery in a matter of weeks, while exposure to high levels of beta radiation may result in third-degree burns requiring long hospitalization and extensive skin grafting.

In early casualties due to fallout in the general vicinity of the nuclear weapon used, one is concerned chiefly with the "recoverable component" of radiation injury. With such fallout pattern, depending on meteorological conditions downwind from the site of detonation, the terrain, weapon, point of detonation, etc., time, intensity and quality factors of irradiation become as important for prognosis, as they are in formulating a radiation prescription for the treatment of malignant disease. From a research standpoint also, the recoverable component of irradiation injury appears to be the key to survival following total body irradiation.

3. Ionization is thought to result in the breakdown products of water in the presence of oxygen into OH, H, O_2H, and H_2O_2; with the exception of hydrogen, these are powerful oxidizing agents. As to the locus of the radiation effects, in cells, two theories are advanced. One, the target theory localizes the action with some vital component of the cells. The other, the indirect theory, relates more

to the general action of the breakdown products of water. Both types of action probably account for radiation injury. One of the most important cellular effects is enzyme alteration. This generally occurs by oxidization of the SH groups or by protein denaturation. There is also a reduction of nucleic acid synthesis and arrest of mitosis. The use of the terms direct and indirect effects of irradiation should distinguish whether one is speaking of a single cell or the whole organism. Thus, ionizing radiation effects on the small bowel epithelium are direct in the sense that they are not appreciably inflamed by shielding various portions of the body other than the area of small intestine irradiated. Such effects within a single proliferating mucosal crypt cell may be both direct and indirect, although the latter, presumably mediated by the production of certain highly reactive radicals, appear to be the most important.

Various tissues of the body respond quite differently, in terms of ultimate effect, to the same cumulative dose of irradiation—total body and otherwise—fractionated in different ways. (See also data by Nachmansohn and Cotzias and Serlin under X, Bl.)

4. As a general rule, the sensitivity of a call to radiation varies as the mitotic activity and inversely as the degree of differentiation. Ranging from the most sensitive to the least sensitive, are the lymphocytes, erythroblasts germinal epithelium of tastes, myloblasts, intestinal crypt epithelium, ovarian germinal cells, basal layer of skin, connective tissue, liver, pancreas, kidney, bone, brain, nerve, and muscle. It is important to distinguish between radiosensitivity and radiocurability as well as the biological effect under consideration.

5. Effects of the whole organism.

(*a*) There is a wide difference in susceptibility of various animals to total body irradiation. The approximate LD 50/30 doses of total body radiation are as follows:

	Roentgens		*Roentgens*
Guinea pig	250	Rat	590
Dog	300–430	Mouse	500–650
Swine	420	Burro	580–780
Man	450 (estimated)	Rabbit	790–875
Monkey	500 [1]	Chicken	1,000
Sheep	520	Turtle	15,000

[1] For servival period of 67 monkeys at various gamma radiation doses see Effects of Barium^{140}–Lanthanum^{140} etc., under B.1. For recent review of the Effects of Radiation in Mammals, E. P. Cronkite and V. P. Bond, American Review of Physiology, vol. 18, 1956.

The difference in the lethal dose of total body irradiation upon various mammalian species: guinea pig, 200 roentgens, rabbits, 800 roentgens, has been directly correlated with degree of the recovery of delay in bone marrow produced in the particular species involved by such dose.

(*b*) Micro-organisms vary tremendously in their susceptibility to radiation. To destroy all bacteria in milk, for example, requires at least 750,000 roentgens. Tobacco mosaic virus requires 1,800,000 roentgens.

(1) Position of man: There are no exact data. The LD50 figure of 350 roentgens proposed from the Marshallese contrasts with a commonly quoted value of 400 roentgens or 450 roentgens. (Handbook of Atomic Weapons for Medical Officers prepared by the Armed Forces Medical Policy Council for the Army, Navy, and Air Force, June 1951), and a recent evaluation of the Japanese World War II casualty data something in figures well bove 400 to 450 roentgens for the immediate radiation from the bomb. (See Marshallese report).

6. The clinical syndrome in man of radiation injury in the sublethal and lethal range presents a fairly uniform hematopoietic pattern. In the sublethal group, there is an early and profound drop in lymphocytes with the neutrophil count showing an initial rise in 12 to 48 hours and then falling to pre-exposure level with a maximum drop from 5 to 6 weeks. Platelets start to decrease in a few weeks with a maximum low in about one month. During the first few weeks the hematocrit falls off only slightly if there is no bleeding. In the lethal ranges the same course of events occur but are markedly acceleraed and of greater intensity. The platelets drop off by the 4th day and completely disappear by the 10th. This general hematopoietic depression ties in with the subsequent bleeding and infection susceptibility. In the delayed effects the shortening of life span may result from such general factors as lowered immunity, damage to connective tissue, and premature aging. The question of specific tissue damage is indicated by the increased tendency to leukemia and skin cancer in certain exposed individuals. However, the carcinogenic factor is not too well established in humans.

For syndrome of nervous symptoms, see joint report of Hiroshima and Nagasaki casualties, etc., by Shiraki et al., under X, B,1. Also in National Academy Sciences report, 452, pages v-5–v-62.

G. Relationships of damage mechanisms to dosages

1. Production of leukemia and neoplasms (under mechanisms and response of man to radiation and radioactivity) exposure to ionizing radiation has been generally accepted as a leukemogenic factor in man (Kaplan, H. S., Cancer Research, 14, 535, 1954).

The high incidence of leukemia in radiologists, 8 to 10 times the incidence in nonradiologists has been widely accepted as evidence of this factor (Ulrich, H., New England Journal of Medicine, 234: 45, 1946). Further evidence has been the cases of leukemia and malignant epithelial lesions (Hepatomas) many years after the diagnostic use of Thorium dioxide (Thorotrast).

More recent evidence is the preliminary report from England in 1956 on the apparent increased incidence of leukemias in children following exposure to weak irradiation received through prenatal diagnostic pelvimetry (Stewart, A., Webb, J., Giles, D., and Hewitt, D., Lancet 2: 447, 1956).

Aplastic anemia: It is well known that the atomic bomb victims that survived the blast and were exposed to extensive radiation died with aplastic or hypoplastic bone marrows. The sequence of the morphologic changes in the bone marrow have clearly been described by Liebow, Warren, and DeCoursey (American Journal of Pathology 25: 853, 1949). In experimental animals evaluation of bone marrow radiosensitivity indicates a variation in degree of sensitivity of the hematopoietic elements with the granulocytic and erythroid elements being most sensitive and fat cells and reticulum cells the least sensitive and even quite radioresistant (Bloom, M. A., and Bloom, W., Journal of Laboratory and Clinical Medicine, 32: 654, 1947). However, more recent studies have indicated that erythropoietic elements are definitely less sensitive than granulocytic (Valentine, W. N., and Pearce, M. L., Blood, 7: 1, 1952).

The use of repeated large whole-body irradiation exposures has been studied by Valentine, Pearce, and Lawrence in the cat using 4 exposures of 200 r over a period of 1½ years. Although the exact L. D. 50/30 days is not known, their preliminary work indicated that probably was in the 300 to 350 r range.

Nevertheless, a single dose of 200 r represented a severe hematologic insult. Recovery occurred within 30 days following each exposure with very little detectible marrow damage after four exposures. (Valentine, W. N., Pearce, M. L., and Lawrence, J. S., Blood 7: 14, 1952.)

For a population of 100 million with a lifespan like that of the United States, each absorbed roentgen of whole-body radiation would result in about 6,000 cases of leukemia during their life time, while one-tenth the "maximum permissible dose" of Sr^{90} would result in 35,000 cases. (E. B. Lewis, Leukemia and Ionizing Radiation. Science, 1957, 125 in press.)

GENETIC EFFECTS

H. The nature of genetic effects: Studies, beginning with Mendel, demonstrated that the characteristics of living things were inherited following certain specific laws. Animal-husbandry men and farmers knew most of this but could not interpret the genetics laws properly because of ignorance and lack of information concerning genes and the requirements for expression of inherited characteristics. The germ cells containing only a single set of chromosones which in turn carry only a single set of genes transmit the characteristic of one parent to the child. The child has a double set of chromosones and genes consisting of one set from each parent. Since the characteristic for one parent may be dominant over that of the other, the child will show a mixture of characteristics; some from one parent, some from the other, and some which were common to both parents. Studies with plants, insects, and animals have demonstrated the accuracy of these concepts.

Because there are so many genes and so many variations among the genes for the same characteristic, there is considerable opportunity for variation which in turn permits opportunity to meet changes in the environment. There is still another mechanism which acts as a safeguard to allow the various species to change and thus adapt themselves to severe and marked alterations in the environment. This mechanism is called mutation. It consists of an abrupt, spontaneous change in a gene, producing a change in a recognizable characteristic. Most mutations are detrimental to the species and would be of value

only if there was a considerable change in the environment. It has been estimated that approximately 1 in 10,000 germ cells will undergo such mutation.

Frequency of tangible genetic effects as given by NAS report, i. e., mental defects, epilepsy, congenital malformations, neuromuscular defects, defects in vision or hearing, cutaneous and skeletal defects, or defects in the gastrointestinal or genito-urinary tracts, make up about 4 to 5 percent of all the live births of the United States. Of these about 2 percent are genetically caused. But this is not the natural mutation rate, which also includes lethals, changes in fertility, life span, etc., which are hard to detect and other nonharmful changes (eye color, etc.). Therefore it may be as Muller suggests, more like 1 in every 5, or 20 percent.

Recognized causes for natural mutation are temperature, chemical substances (particularly azone), and radiation. Again based on experiments with insects and animals it has been estimated that radiation equivalent to 30 to 80 r, whole-body dose, will double the normal spontaneous mutation rate. Further it has been demonstrated that the time over which the radiation is received does not affect the mutation rate.

Russell's studies on mutation of seven genes in mice show that about 30 r delivered to immatured germ cells constituted the doubling dose. There is probably not much higher in man, it may even be lower.

Since man exhibits a longer life span than mice and Drosophilia, it is likely that more of the spontaneous mutations are due to background radiation. If it were equal to it (3 r) then the doubling rate would also be 3 r. It is more likely that it is about 3 times as large (10 r) as recommended by the NAS reports.

The frequency of point mutations increases linearly with radiation dosage. In Drosophilia this has been demonstrated for a range from 25 r to 6,000 r. In certain plants this is extended down to 5 r. In mice this has only been tested from 300 to 800 r, but there is no indication that it does not hold outside this range. There is no sign of a threshold below which mutations are not produced, but rather even the lowest are proportionately mutagenic, and all doses are additive or cumulate in effect.

Because gene changes are inherited and because it is very rare for genes to mutate back, the occurrence of a mutation is thereafter inherited until the end of that cell line. Consequently, the effects of mutation accumulate within the population. With random matings these genetic changes become dispersed among the population. If the mutations are detrimental they are likely to cause decreased viability and ultimately death when accumulated in the population to such an extent that both parents transmit the detrimental character to the child. In effect this eliminates the mutant from the population. Ultimately a level is reached whereby for each new mutation arising an old mutant accumulated in the population will be eliminated.

Because of these reasons it has been believed by one group of investigators led by Muller that any increase in radiation can only be harmful and ultimately will lead to degradation and degeneration of the race. However, this will require many generations before such effects could become apparent. A smaller group believes that there are certain inherent safeguards which would protect the species by decreasing mutation rate in response to radiation.

Sturtevant of the California Institute of Technology has calculated that, if the irradiation from fallout increases at its present rate, it will produce some 70 children a year carrying a mutation. This estimate he adds may be too low and, in fact 7,000 may be a better estimate. This has no noticeable impact statistically, that is, about 2 percent (150) will actually show changes from the normal. If compared to the 4 million born yearly and 40,000 defective ones at birth we need not be concerned about the effect of fallout on the future of the people at large or on mankind. Yet if the statistical approach is not used 150 individual newborn children each year will be affected.

Some of the current problems in this field are discussed in the following articles:

Crow, James F., The Estimation of Spontaneous and Radiation-Induced Mutation Rates in Man, from Eugenics Quarterly, vol. 3, page 201, 1956.

Crow, James F., Possible Consequences of an Increased Mutation Rate, from Eugenics Quarterly, in press.

Glass, H. B., The Induction of Mutations with Radiation, talk delivered at International Agency for Peaceful Application of Atomic Energy, Brookhaven National Laboratory, May 15, 1957.

Stern, Curt, Genetics in the Atomic Age, from Eugenics Quarterly, vol. 3, page 131, 1956.
Muller, H. J., Potential Hazards of Radiation, from Excerpta Medica (Amsterdam) in press.
Muller, H. J., Damage from Point Mutations in Relation to Radiation Dose and Biological Conditions, in press.

L. Concepts and definitions for standards pertaining to external radiation effects are covered in Relative Biological Efficiency of Different Ionizing Radiations, John W. Borg, National Bureau of Standards Report 2946, December 30, 1953.

M. Standards for internal radiation effects:

1. Reference is made to the report of the Subcommittee on Toxicity of Internal Emitters as given in Pathologic Effects of Atomic Radiation, National Academy of Sciences—National Research Council publication 452.

Also reference is made to the report Tentative Recommendation of the NCRP for the Maximum Permissible Levels of Radiation to Man, a copy of which is attached.

2. For methods of determining total accumulated doses and dose rates from external radiation, see Doses and Dose Rate Cures, AFSWP Manual No. 99.

N. ———.

SPECIFIC QUESTIONS FOR DISCUSSION

A. All low level effects are not extrapolations from high level effects, (for example see studies by E. Lorenz). Such extrapolations would be hazardous. However, further studies on low-level effects are particularly important since the explosion on March 1, 1954, of an experimental thermonuclear device at the United States Atomic Energy Commission Eniwetok Proving Grounds in the Marshall Islands.

B. There are quite definite distinctions between temporary and permanent (long-term) damages, and between repairable and irrepairable damage. The problem of certain long-term damages may be complicated by sequelae from effects upon tissues other than the one(s) in which the most serious lesion(s) may ultimately appear, as in the development of certain neoplasms. This has been demonstrated in the case of malignant tumors arising in the thymus following irradiation by Kaplan, and may be true also for certain other types of neoplasms arising many years after exposure, as an example, in the skin. While repairable effects are well known, the differential sensitivity of anatomical units of an apparently, morphologically, homogenous tissue may result in incomplete recovery of a sufficient number of components after high doses to result in death of the organism. Recovery of self-replenishing tissues essential to life, such as the bone marrow and small intestine (when the abdomen is the principal site of injury and after supralethal doses of total body radiation) may be sufficiently delayed until sequelae, such as those associated with panhematocytopaenia result in death even though in the case of the bone marrow recovery may still occur if such complications can be controlled.

C. * * *

D. The effects on behavior in Hiroshima and Nagasaki casualities who died during the period of 16 to 69 days is mentioned under Joint Report—Effects of Atomic Radiation on the Brain of Man, Etc., by Shiraki, et al., under X, B-1. There was little evidence of changes in mental posture, personality, and intelligence in those who died during the first 3 months after exposure. Under such conditions the dose level was great enough to cause death from anemia and other factors, but was insufficient to affect directly the brain. Japanese physicians have stated that many patients who survived the bombings have shown no neurological disabilities but have complained of generalized weakness, easy fatigability, and nervousness for years after the bombings.

E. To date we are probably limited for practical purposes in the event of mass casualities due to exposure to ionizing radiation to procedures which will (1) reduce the dose received by such things as shelter, evacuation, clothing, bathing, washing down ships of the fleet, etc.; (2) reduce and combat complications such as burns, indirect injuries from blast effects, and infection; and control the sequelae of panhematocytopaenia, and disturbances in water and electrolyte balance, by procedures in general use for such syndrones from any cause. The possibility of adding to this armamentarium by more specific therapeutic measures, including both humoral and cellular factors appears probable from research to date, but has not been consummated.

F. Unless all radiological factors are reported, and radiation procedures such as fluoroscopy standardized as far as practical, a record of the number of roentgens received by each person during his lifetime would probably not be very meaningful. For example, to record the fact that on a film badge a patient received 10 roentgens, per se, is no more informative than a statement that he was given 10 milliliters of a substance intravenously without indicating the concentration of the solution.

G. The total estimated dose rate to gonads from natural sources of radiation both internal and external is 0.095 roentgens per year. In addition it is estimated that diagnostic radiology contributes 22 percent of the above natural radiation dose. Occupational exposure in radiology and industry adds at least another 1.6 percent of the natural radiation dose. (The Hazard to Man of Nuclear and Allied Radiation, presented to the Lord President of the Council to Parliament by Command of Her Majesty, June 1956.) H. (The numbering of the questions skips from H to J).

J. * * *

K. Radioiodine acts principally on the thyroid, but a possible relationship to leukopenia and anemia has been suggested. The doses and expected effects are as follows:

(*a*) 1 or 2 milliocuries I^{131}: This is the lowest amount that will cause transient alteration of physiological activity of the thyroid. No recognizable histologic changes would be expected.

(*b*) 10 to 15 millicuries I^{131}: This amount will cause a mild transient decrease of thyroid activity, probably detectable only by laboratory tests. The depression may last a few months. Histologic alterations, if any, would be in the form of mild fibrosis and slight los of follicular epithelium.

(*c*) 35 to 75 millicuries I^{131}: Usually given in fractional doses, this total amount can be expected to produce definite clinical hypothyroid state for between 6 and 12 months. Histologically, there would be varying degrees of fibrosis and follicle destruction.

(*d*) Two courses of 35 to 75 millicuries I^{131} can be expected to produce almost complete cessation of thyroid function with severe myxedema. The duration of the myxedema cannot be predicted, as the patients tend to develop thyroid activity over the course of a few years. Histologically, one would expect virtually complete fibrosis of thyroid with a few surviving distorted epithelial cells and possibly a few distorted follicles. Eventually, some regeneration of follicles might occur. Even though there may be widespread destruction of thyroid, the parathyroids are unaffected.

(*e*) 1,200 to 1,500 millicuries: This total amount has been given over a period of several years to a few patients. Leukopenia and/or anemia has sometimes developed and been attributed to the radiation effect or circulating I^{131}, but there is no proof that the hematologic changes were due to I^{131}. Amenorrhea has been reported, but there is no proof it was the result of I^{131}.

Cs^{137}: There is no evidence so far that Cs^{137} has any unusual biological properties. It does not seem to localize in bone.

C^{14}: This is eliminated fairly rapidly (about 97 percent in 3 or 4 days) from the body, largely as CO_2. It does not localize in bone.

L. * * *

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BIOGRAPHICAL SKETCHES OF WITNESSES WHO CONTRIBUTED TO STATEMENT BY ARMED FORCES INSTITUTE OF PATHOLOGY

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Representative HOLIFIELD. Our next witness is Dr. Austin M. Brues, of the Argonne National Laboratory, director of the Biological and Medical Research Division since 1946, and delegate to the U. N. Radiation Committee.

All right, Dr. Brues.

STATEMENT OF DR. AUSTIN BRUES, DIRECTOR, BIOLOGICAL AND MEDICAL RESEARCH DIVISION, ARGONNE NATIONAL LABORATORY [1]

Dr. BRUES. Thank you, Mr. Chairman.

I do have a short prepared statement which I intend to read in its entirety.

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Representative HOLIFIELD. All right.

Dr. BRUES. I want to speak chiefly concerning the philosophy of setting and determining the permissible levels which Dr. Taylor spoke of earlier this morning, and what the true basis of our understanding of these is.

The presently accepted safe levels of radiation and of radioisotope incorporation are based on a long history of clinical observation and experimental research. These levels have been determined on the basis of making the most pessimistic assumptions where knowledge is lacking and then introducing a factor of safety.

Where direct observations on human beings or suitable animals have been at hand, the practice has been to divide those levels which produce any detectable effects by 10 to arrive at a permissible level. It was on this basis that the permissible daily X-ray exposure of 0.2 roentgen to the whole body was reduced many years ago to 0.1 roentgen, and then, as a result of some further work which was done during the Manhattan District days, particularly having to do with the production of sperm in dogs given one-half roentgen a day, which showed dogs had some changes in the rate at which they produced a sperm, it was considered one-twentieth of a roentgen a day would be a safer dose.

The question then came up as to whether these levels had to be adhered to each day or whether one might not receive a week's dosage on Monday morning without any further effect than that incurred by spreading it through the week. While an acutely dangerous dose of radiation—say 500 roentgens—is less toxic if spread out over a week owing to the rapid recovery of the blood-forming tissues, there seemed to be good experimental evidence that the late consequences of low doses were rather independent of time, and so three-tenths of a roentgen per week was accepted. It seems quite likely that the whole yearly quota of 15 roentgens—which in itself produce no obvious effects—might as well be incurred on a single day, but three-tenths per week appears to be more practical, except for special cases such as might arise under civilian defense conditions, where a calculated risk might be acceptable.

That sort of thing has also been allowed for.

Ingestion or inhalation of radioactive substances presents a different problem. These sources of radiation may become concentrated in certain tissues and organs, and the greater part of the radiation energy, depending on type, may be given locally. The most striking example of this is the concentration of radioactive iodine in the thyroid gland, where half of the dose may be deposited in one one-thousandth of the body. We do not, unfortunately, for purposes of cancer treatment, know of any other such striking case of an extreme localization.

There have been two ways of solving this question. One has been to calculate the radiation dose in the "critical organ," that is, the organ with the highest radioactive concentration, and then to set levels of exposure such that the equivalent of three-tenths roentgen a week will not be exceeded. The other has been—and this is used where the bony tissues receive the highest dose—to compare the possible damage with that produced by radium in the human skeleton, since we have knowledge derived directly from the histories of persons who have been poisoned by radium through industrial exposure in the watch dial painting business or through administration of

radium as a drug in the days, 25 to 30 years ago, when it was thought that radium might be beneficial in certain conditions for which there was no known effective treatment.

Since no damage had been observed in patients who retained less than 1 microcurie of radium in the skeleton, about the amount in a radioactive watch, this was again divided by 10 and one-tenth microcurie was established as a permissible amount of radium. To this day, no detrimental effects have been seen in persons containing this amount of radium.

Since the preparations used to paint luminous watch dials and for some medical uses contained considerable amounts of other radioactive elements—specifically mesothorium—it has been suggested that pure radium may be less toxic than indicated here. This point is not settled, and a search is being made for other persons who may contain abnormal amounts of radium in order to improve our knowledge. In particular, it is becoming clear that a good number of persons may harbor more than 1 microcurie without detectable harm of any sort, and that the proportion who do suffer for a given amount is lower than was believed.

Since the first cases seen, and the majority, were found out because they had complaints which directed the attention of physicians to them, we see a selected group of people who met with the worst result; the well ones are much less likely to come to our attention.

This, again, I think, introduces somewhat a factor of safety in the question of how much radium is likely to produce serious effects on the human being.

These radium levels have been transferred to other radioactive materials as a result of comparing effects of radium on animals against those of plutonium or radioactive strontium. Plutonium turns out to be somewhat more toxic than would be expected from physical calculations of the radiation to bone, and this is apparently because plutonium is deposited near those cells which are active in bone growth.

Radioactive strontium 90 has been determined to be one-tenth or less as likely to produce bone tumors as radium for a given number of microcuries. On this basis, 1 microcurie of strontium 90 is considered as the equivalent of one-tenth microcurie of radium and, therefore, is designated as the maximum permissible level.

These levels were employed very successfully in the atomic-bomb project during wartime. Most of the workers remained very far below the permissible levels.

If you set up a level which is not to be exceeded, it happens, administratively, that things work out so that people get very much less.

There is the story of one individual on the project who attempted to receive his 10th roentgen per day because that is what he thought he was supposed to do. But, in general, nothing like this happened.

For practical purposes it is necessary to determine many more things than just the safe level of body content. We must also translate this into the amount which can safely exist in the air breathed and in the food and water ingested, in order to regulate these concentrations at a level which will not permit an excessive load to exist in the body. These are, then, the MPC's, or maximum permissible concentrations. This means we must use our best information as to how much is retained in the body from inhalation and from the digestive tract, and how fast it is lost from the body by excretory processes.

Many of these things have to be decided upon before the enormous amount of experimental work required for an exact answer can be carried out. There is no time here to discuss all this, but I can say that those committees shouldered with responsibility for such decisions always use the strictest possible assumptions, and, since several separate assumptions must be made—for example, how much in the air gets into the lung, how much in the lung is kept there until it gets into the circulation, how much of that is deposited, and how fast it is lost from the organ—as well as the relative effects of types of radiations from different elements, each of these considered in the worst light, we end up by multiplying a number of different factors of safety and are almost certain to come out with a level much lower than the correct one.

To give a few examples:

When tritium was first under consideration, it was noted that it has a remarkably short-range beta radiation, and nothing like it had been studied experimentally. So a factor of safety of 10 was introduced until it was shown that it acts about the same as the more familiar radiations, when this factor could be thrown out. Similarly, the strontium and radium levels were based on an early assumpion that they are lost from the bone according to a very slow process, which was measured on patients and animals a long time after its acquisition. This led to very low levels being recommended in water. It has since become known that loss occurs very rapidly at first, so that it requires about 10 times as much taken in to maintain a given level. The MPC's in this case have not yet been changed until complete study of the problem can be made, although the evidence is now fairly clear.

In another instance, a stringent level of radium in water was suggested unofficially, and we found that it was actually less than that in the drinking water of our laboratory. Had this been adopted, we would have been required to distill our own domestic supply before we could be permitted to let it flow off the grounds.

Of course, radioactive materials, as you have probably heard in the last few days, because of their special nature and the degree of development of our instrumentation, can be detected in relatively much smaller amounts than almost any other toxic material. This may be a large part of the reason for the disproportionate public concern about radioactivity relative to other noxious things.

As you are aware, there has been a general lowering of levels recently, since artifically produced radioactivity has become wider in its scope.

Here, we have to keep two things quite distinct. First is the problem of genetic effects, which will be discussed by others. The special features of these is that they seem to be produced without threshold: that is, any small amount of radiation will produce its proportion of changed genes; and that almost all of these are hidden and are perpetuated through generations till they come together accidentally through interbreeding. Thus, very stringent levels are recommended, but they do not refer to any individual but to the whole population; thus an average figure for the whole population is all that is to be looked for.

The other is concerned with the matter that we must not only consider, as was the basis of the original levels, a selected group of in-

dustrially exposed persons, but also many persons outside this group who might be close to installations where exposures could occur.

One asks, of course, why if a level is safe for one group, it is not for another. There are several reasons for this, none complete in itself. One is that the occupationally exposed group are selected, do their work voluntarily, are under medical control and are monitored. Another is that persons not in the atomic energy business may be in other fields of work which have their own peculiar hazards. Still another may be that there are more chances for an overexposure to occur. So that we might set the levels so that a considerable "overexposure," on that basis, would still not be an overexposure in the sense that it get to a level which would be within the potential danger zone. For these and other reasons, in one sense or another philosophical, we have adopted another safety factor of 10.

Mr. RAMEY. On our last point there, about your safety factor of 10 with respect to strontium 90, would the fact it applies mostly to the takeup of strontium 90 as it affects persons that it would be more as it applies to children, and therefore a lower factor when you go from an occupational group to a population group to take into account the bone-forming period?

Dr. BRUES. Well, this question has been raised. Actually I do not know of evidence that the skeleton of the child is more sensitive, except with respect to the fact that if one starts as a child and continues to an adult, he puts more of the material away. This, I think, has already been taken into consideration. We could still have more evidence on this, but data I have seen does not suggest the child at these low levels, where not stunting his growth, is going to show any more results than certain total amounts for others.

Representative HOLIFIELD. It is a fact that the bones of a child are growing and accumulating more cells at a faster rate of cell growth than the adult, is he not?

Dr. BRUES. That is true, yes; and on a given intake level, a larger total will be evident.

Another consideration which has led to extra safety is that of the fluctuating level of exposure. Where we have set conditions for exposure to external radiation we have allowed for such fluctuations. It seems equally reasonable for the level to say, radioactive strontium in water to exceed the MPC by 7 times 1 day a week; or for the point of disposal in a highly polluted river to exceed the MPC so long as it is diluted out before it reaches a point where it would conceivably be ingested—remembering also, that the MPC is based on the assumption of continuous intake for a lifetime. The same situation applies to shifting winds around a stack. For exadministrative reasons, it is therefore highly likely that conditions will be set which are much more stringent than those leading to a maximum possible concentration in personnel. It is most important to remember that that is what we are really concerned with, and that no legal culpability should be involved in an occasional fluctuation in the environment above that which would be one-tenth or one-hundredth of a dangerous level but only if it were kept up indefinitely.

The whole basis of the concept of a permissible amount, or level, by the way, rests on the assumption that there is a threshold; that is, that no harm will be done by smaller amounts. In genetics, we have reason to doubt that there is a threshold at all, so that the total popula-

tion average of exposure is set so low that it falls close to the natural variations in the natural radiation background.

Where the question is applied to other effects of radiation, such as longevity or cancer, we do not know whether they have thresholds or not. It has been suggested that they do not, but on the basis of very scanty evidence so far, and in no case is there information much below 100 r; and there are also good reasons from what we know about the nature of cancer to suspect that the hazard goes down faster than the insulating agent. An animal experiment to guarantee the existence of a human threshold below suggested off-site MPC's would be a prodigious undertaking and would drain off much of our talent from work which is really more basic to the problem. It would, moreover, detract both talent and public attention from problems of the same sort that seem, to me at least, as urgent.

For instance, millions of Americans now living will die of cancer of the lung due to something in the environment that we did not have a few decades ago. I once made a calculation by exactly the same means as are used in the calculations of MPC's, comparing lung cancer with radium cancer, and derived an MPC—occupational criteria—of 2.4 cigarettes a day. An off-site MPC would be 1 every 4 days. The only assumption made here was that cigarettes are the causative agent. If it is city smoke, this would have to be reduced in a similar proportion before the criteria used in determining permissible levels of radioactive substances would find it allowable.

Senator ANDERSON. What year would become a basis for this new item which has come into the picture? You say something about decades. How far back?

Dr. BRUES. These figures, of course, vary from place to place, and they have been coming up more slowly in the female than in the male. But in general there has been at least a tenfold increase in lung cancer since 1900, in the rates for age since 1910 up to the decade 1940–50. This is apparently still rising at a considerable rate, and, as I say, people are very much concerned about this problem.

Senator ANDERSON. Particularly with all the millions of dollars we are spending on cancer research. The more we study it, the worse it appears to get.

Dr. BRUES. This may be repeating my colleague slightly, but I will mention it again.

If we are to settle the question of threshold satisfactorily, I would say that we should carry out expanded studies on large populations of animals, but not rely on this to the extent of reducing the amount of basic work which will probably lead us sooner to a clear answer. I refer to many things, but chiefly studies on the nature and origin of cancer, the effects of radiation on cells, the nature of the aging process—for example, why a mouse lives little more than four score weeks and ten—and broad studies of medical and population statistics in relation to natural radiation.

Along with this are the whole unexplored fields within the medical and biological sciences, any one of which might turn out to be crucial to the radiation problem; recruiting and training good talent; and communication of scientific research findings.

As one who sits on various committees to discuss and, we hope, solve these problems, I am also impressed with the danger that more and

more of the best talent and time for the imaginative approach to these questions may be drawn away from the work and thought that they ought to be producing, into more and more debate over the same scanty knowledge.

May I just conclude with what might be a scientific parable, by pointing up the potential difficulties of the whole problem from an experiment done by the late Dr. Egon Lorenz.

Dr. Lorenz carried out the lowest-level experiment in chronic irradiation that has been done, giving mice a little over 0.1 roentgen daily throughout their life. He found, and thus confirmed an earlier experiment, that the irradiated mice developed more leukemias than those that were not irradiated, but that their average life span was almost 10 percent longer.

What a mouse would do in this case if he had a free choice, I am not sure.

Representative HOLIFIELD. Thank you very much, Dr. Brues, for your illuminating discussion.

Are there any questions?

Senator BRICKER. You would not want to conclude from that, if a human being was given 1 roentgen a day for his life, he would live 10 percent longer, would you, Dr. Brues?

Dr. BRUES. No, sir. Part of the parable was to say that I do not like to extrapolate animal experiments to man until they have reached a fairly good degree of ramification.

Senator BRICKER. I would not want to give him his free choice in that case.

Representative HOLIFIELD. The chart that Dr. Friedell gave in his statement showed that a lethal dose of 50 percent would apply to dogs, 350 roentgens; mice, 450 roentgens; monkeys, 500 roentgens. So that seems to be the nearest reaction as between your permissible dose of 400 roentgens to animals you are experimenting on. Is that right?

Dr. BRUES. That is right.

We do not know that the acute results run into the same proportions as late chronic effects.

Representative HOLIFIELD. There must have been some reason why they were in the same dose range, rather than rabbits, at 800, bacteria at 100,000 roentgens.

Dr. BRUES. The mammals do run, as far as acute kill goes, between perhaps 300 and 900. There is that degree of variation between the species, and this is just the amount that will kill them in a couple of weeks.

Representative HOLIFIELD. But you draw no parallel between setting the lethal dose of roentgens for man in that category?

Dr. BRUES. I would be afraid to.

Representative HOLIFIELD. Are there any further questions?

Thank you very much.

We will adjourn now until 2 o'clock, when we will have Dr. E. P. Cronkite, Dr. Edward Lewis, and Dr. Shields Warren as our witnesses this afternoon.

(Whereupon, at 12:45 p. m., the committee was recessed, to reconvene at 2 p. m., of the same day.)